AUGUST, 1956

STACKS

JOURNAL OF THE IRON AND STEEL INSTITUTE

4 GROSVENOR GARDENS · LONDON S W I

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VOL. 183 PART 4

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Report of Annual Meeting, 1956

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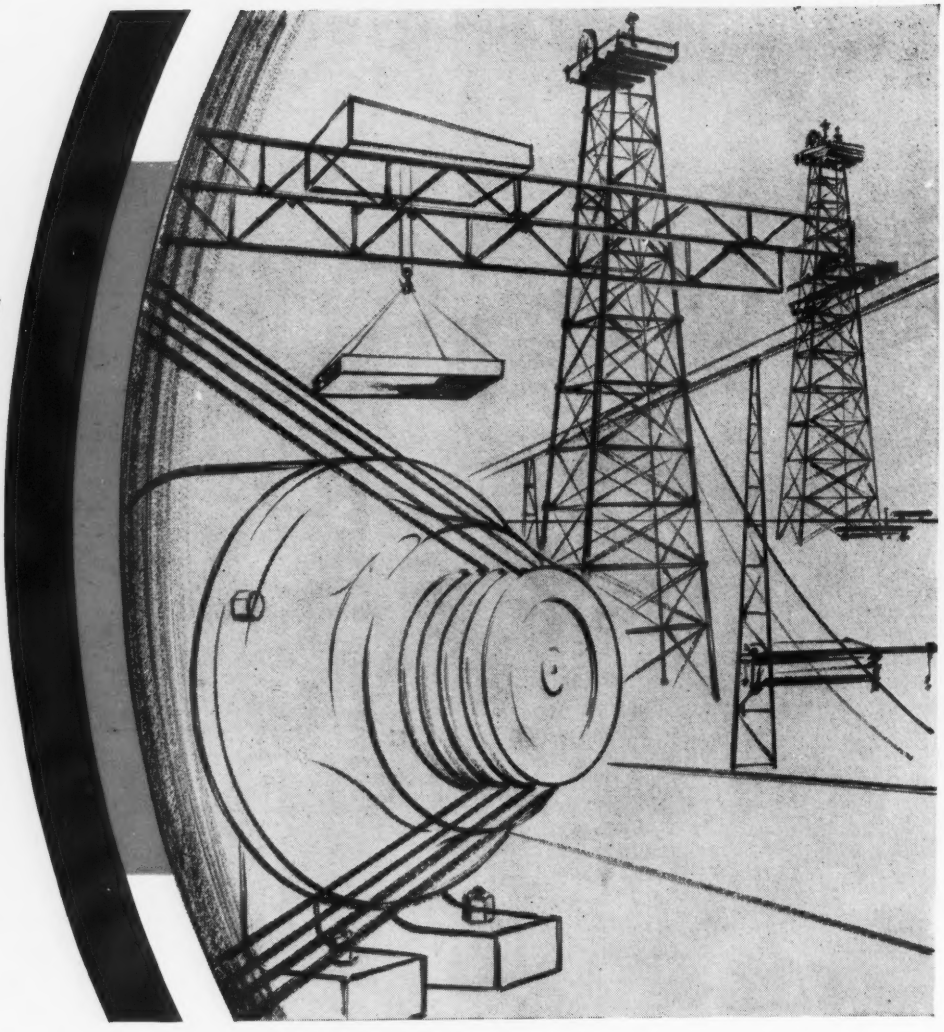
When industry gets tough Ferodo can take it



Industry asks a lot of a friction lining. Yet Ferodo Friction linings have proved they can easily cope with the heaviest loads.

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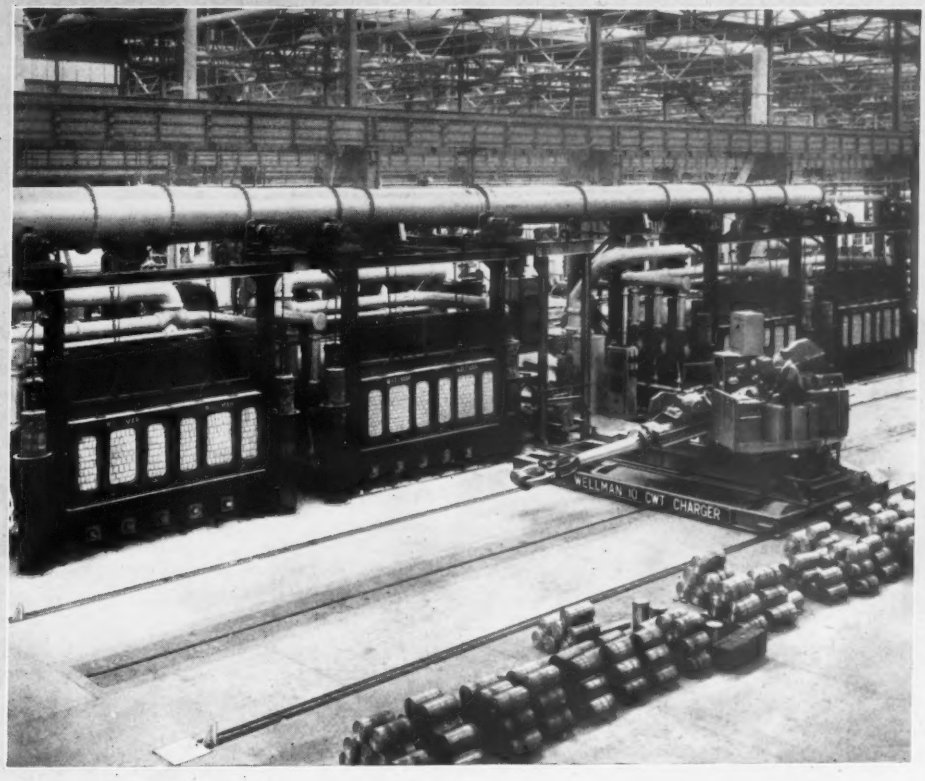

Four Wellman Batch Billet Reheating Furnaces and 10-cwt. Ground type Revolving Billet Charging Machine having rotating Grips, recently installed at the new Hereford Works of Messrs. Henry Wiggin & Co. Ltd. This Wellman installation also includes two Pack Reheating Furnaces, one Continuous Bar Reheating Furnace with 10-ton Billet Pusher, also 15-ton and 30-ton Electric Overhead Travelling Cranes.

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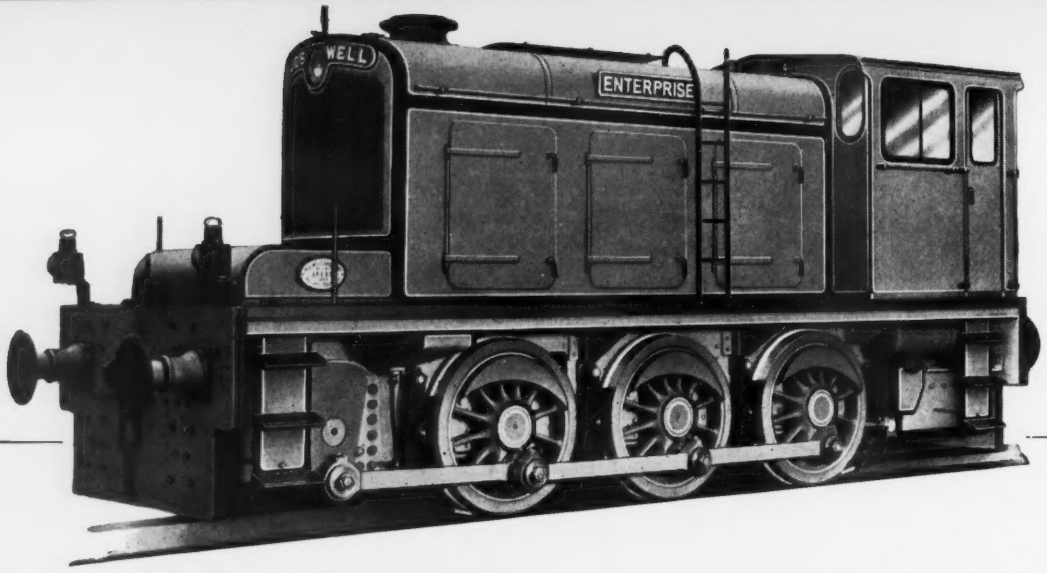

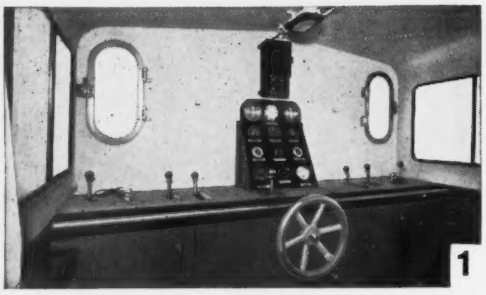
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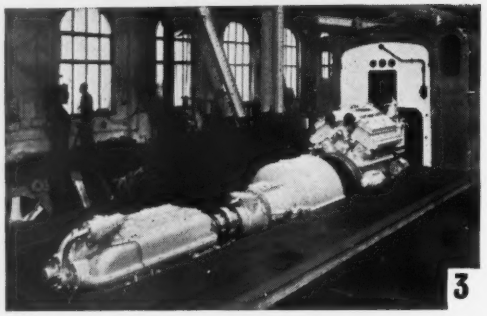
3

'Enterprise', the New Hi-Dyne dual fluid drive locomotive

The Hi-Dyne Engine, Dual Fluid Drive Locomotive (weight 50 tons) is suitable for the following duties

30 ton Locomotive Tractive Effort 16500 lbs. for Shunting

40 ton Locomotive Tractive Effort 22500 lbs. for Shunting & Hump Shunting

50 ton Locomotive Tractive Effort 27750 lbs. for Shunting & Transfer Traffic

80 ton Locomotive Tractive Effort 36000 lbs. for Passenger & Mixed Traffic

1. *The cab layout. The central forward-and-reverse handle, with which is combined the high-and-low alternative ranges, is centrally located; the other controls are duplicated.*

2. *'Enterprise' at the head of a coal train*

3. *Installation in the locomotive 'Enterprise' showing left to right, the final reduction gearbox, the Dual Fluidrive transmission, and the Paxman V-6 pressure-charged constant h.p. engine.*

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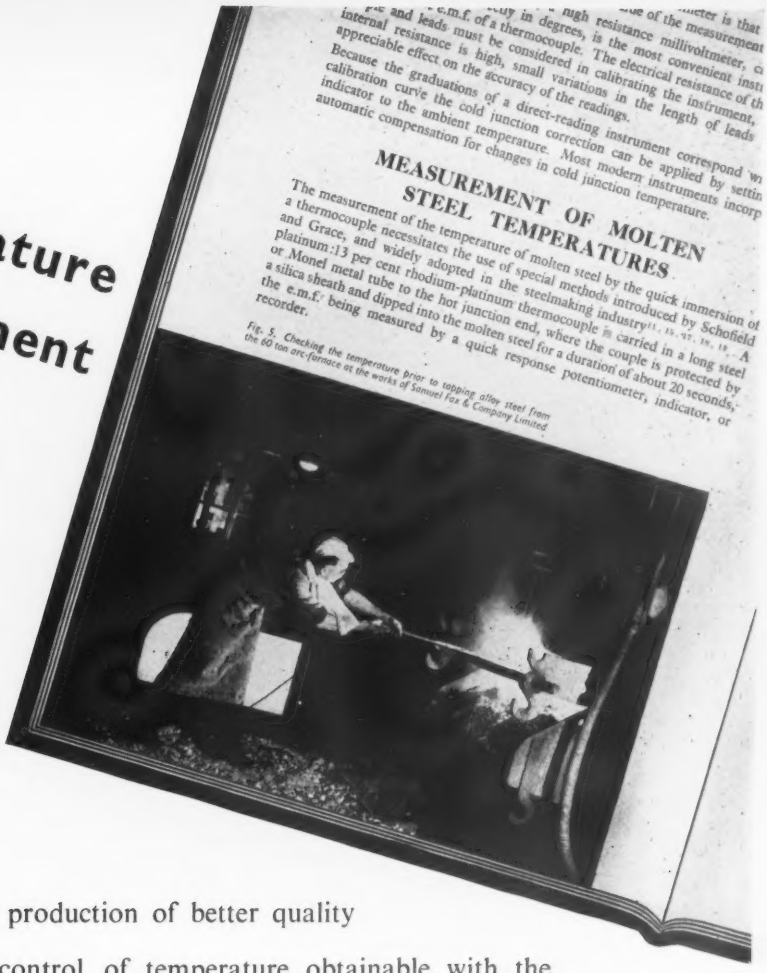
High temperature measurement



...e of the measurement
...nigh resistance millivoltmeter, c
...e.m.f. of a thermocouple. The electrical resistance of th
...and leads must be considered in calibrating the instrument,
internal resistance is high, small variations in the length of leads
appreciable effect on the accuracy of the readings.
Because the graduations of a direct-reading instrument correspond w
calibration curve the cold junction correction can be applied by settin
indicator to the ambient temperature. Most modern instruments incorp
automatic compensation for changes in cold junction temperature.

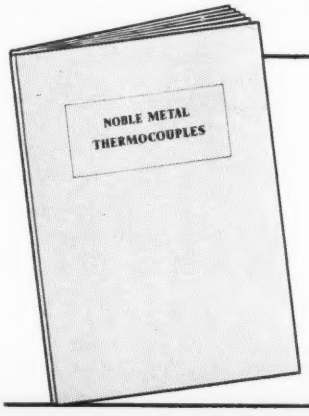
MEASUREMENT OF MOLTEN STEEL TEMPERATURES

The measurement of the temperature of molten steel by the quick immersion of a thermocouple necessitates the use of special methods introduced by Schofield and Grace, and widely adopted in the steelmaking industry[11, 15, 17, 18, 19]. A platinum:13 per cent rhodium-platinum thermocouple is carried in a long steel or Monel metal tube to the hot junction end, where the couple is protected by a silica sheath and dipped into the molten steel for a duration of about 20 seconds, the e.m.f. being measured by a quick response potentiometer, indicator, or recorder.

Fig. 5. Checking the temperature prior to tapping alloy steel from the 60 ton arc-furnace at the works of Samuel Fox & Company Limited.

An important factor in the production of better quality steels has been the closer control of temperature obtainable with the aid of the noble metal thermocouple.

A new Johnson Matthey publication surveys the development of the noble metal couple and discusses its application in modern industry, with special reference to the measurement of liquid steel temperatures.



"Noble Metal Thermocouples" by H. E. Bennett, F.I.M., is free on request.

Johnson Matthey

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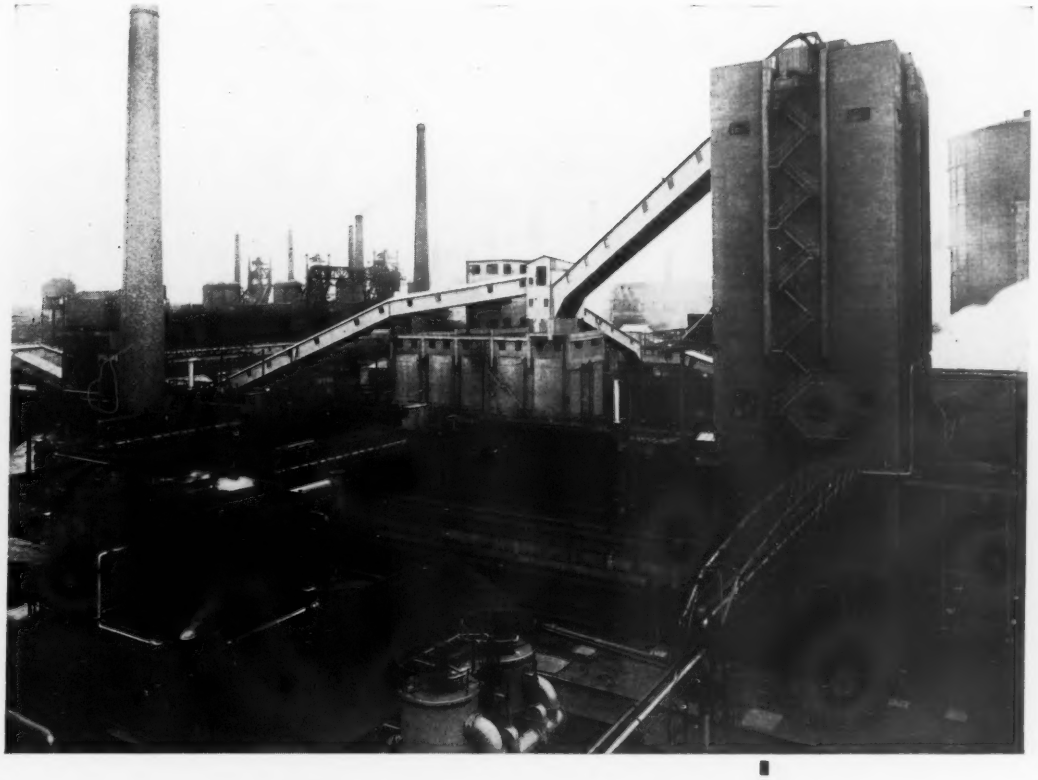
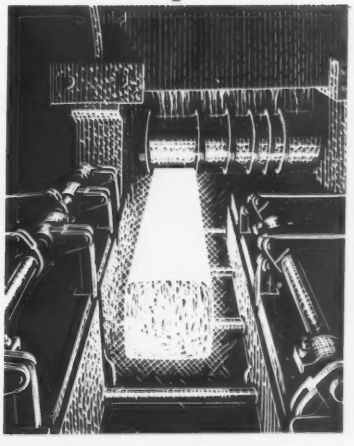
COKE OVENS IN BRITISH STEELWORKS



The Pusher Side of the Fourth Installation—46 W-D Becker Coke Ovens—at the Cardiff Works of Guest Keen Iron & Steel Company Limited. Beyond the Battery and the Coal Blending Bunkers are the 3 previous Installations built in line. Altogether there are 128 W-D Becker Coke Ovens at Cardiff with a daily coal carbonising capacity of 2,679 tons.



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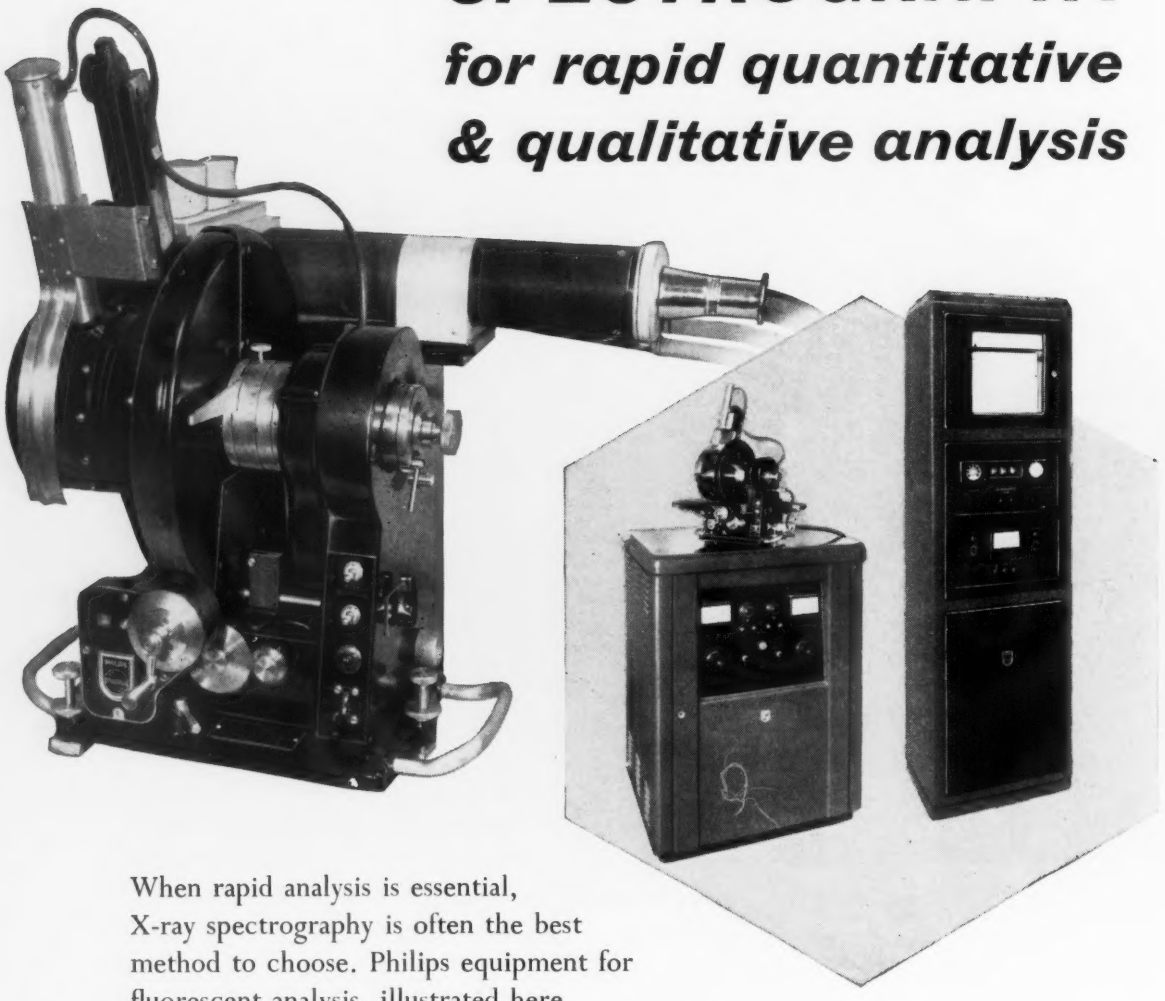

When rapid analysis is essential, X-ray spectrography is often the best method to choose. Philips equipment for fluorescent analysis, illustrated here, comprises: PW. 1010 X-ray diffraction generator with stabilised D.C. output; wide angle goniometer with motor driven scanning and X-ray spectrometer. The automatic recorder enables permanent records to be obtained, even when the apparatus is unattended.

This, and other X-ray diffraction equipment, is described fully in a new 52-page brochure. Send for your free copy today.

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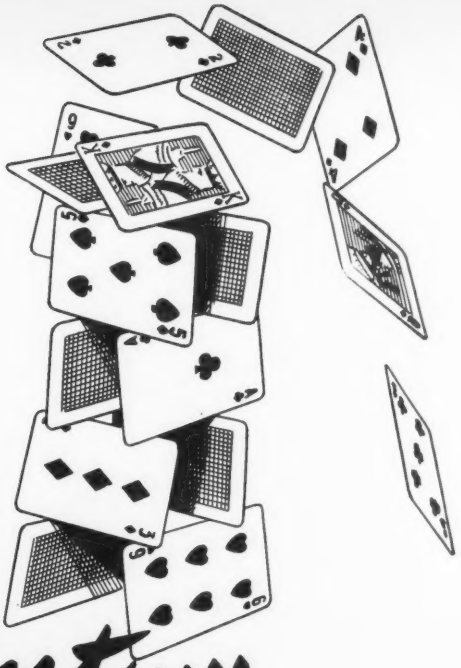

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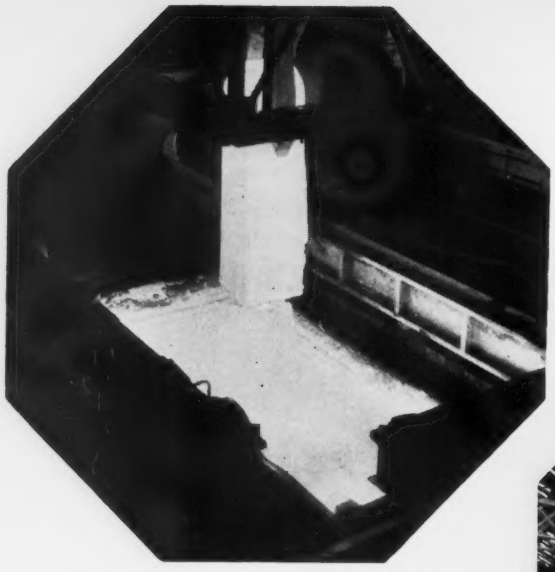
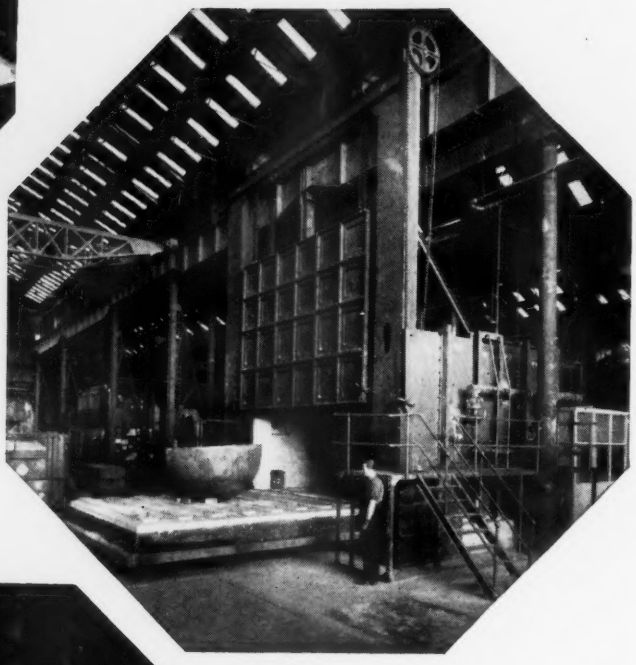




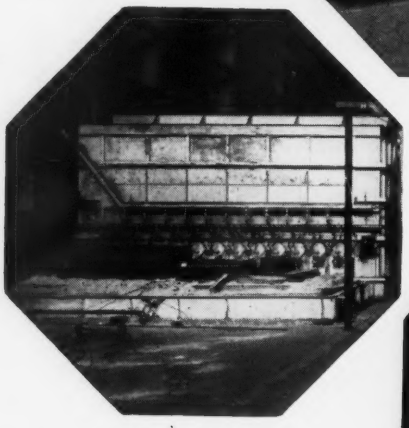
Photograph by courtesy of
Dowson Mason Ltd.

A soaking Pit...

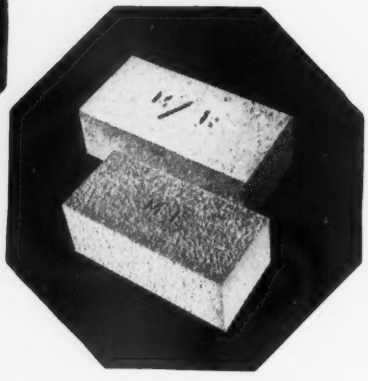
a forge furnace...

an annealing furnace...

things
about which
it can pay
handsomely
to consult



Photograph by courtesy of
Salem Engineering Co., Ltd.



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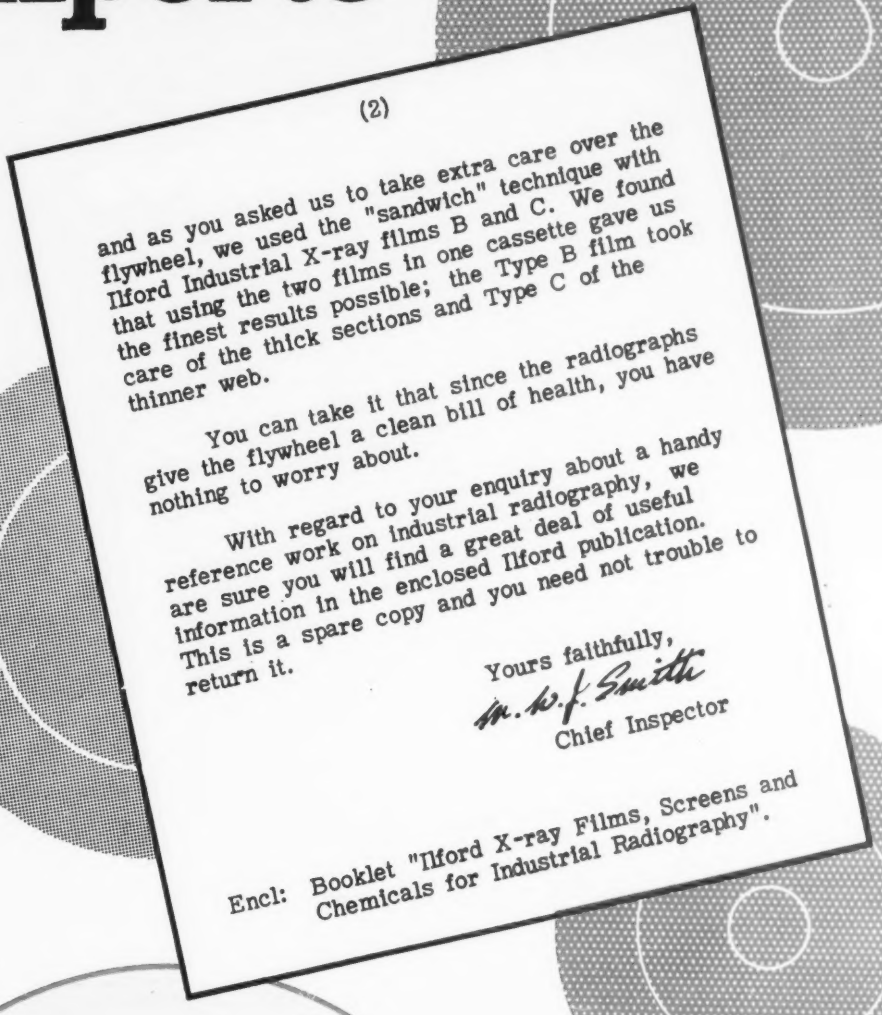
Between experts



(2)

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Chief Inspector

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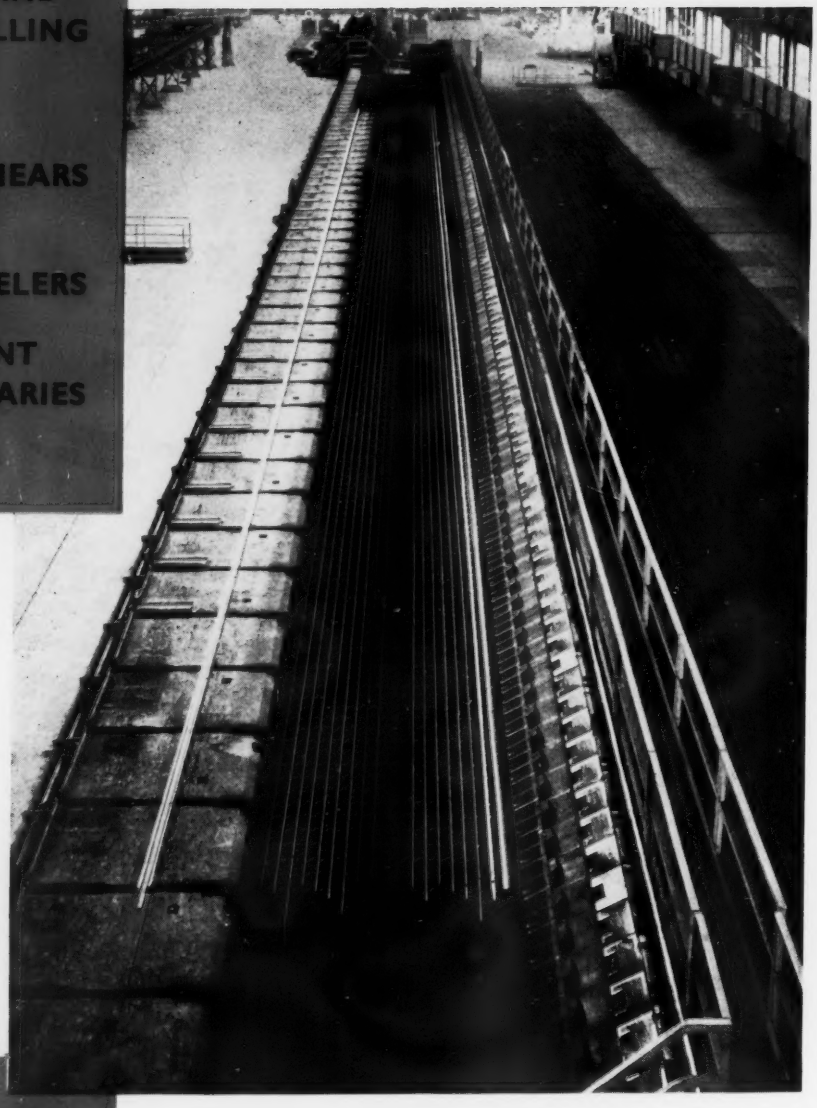

Mechanical Cooling Bed 255 ft. long.

Photograph by courtesy of The Park Gate Iron and Steel Company Limited.

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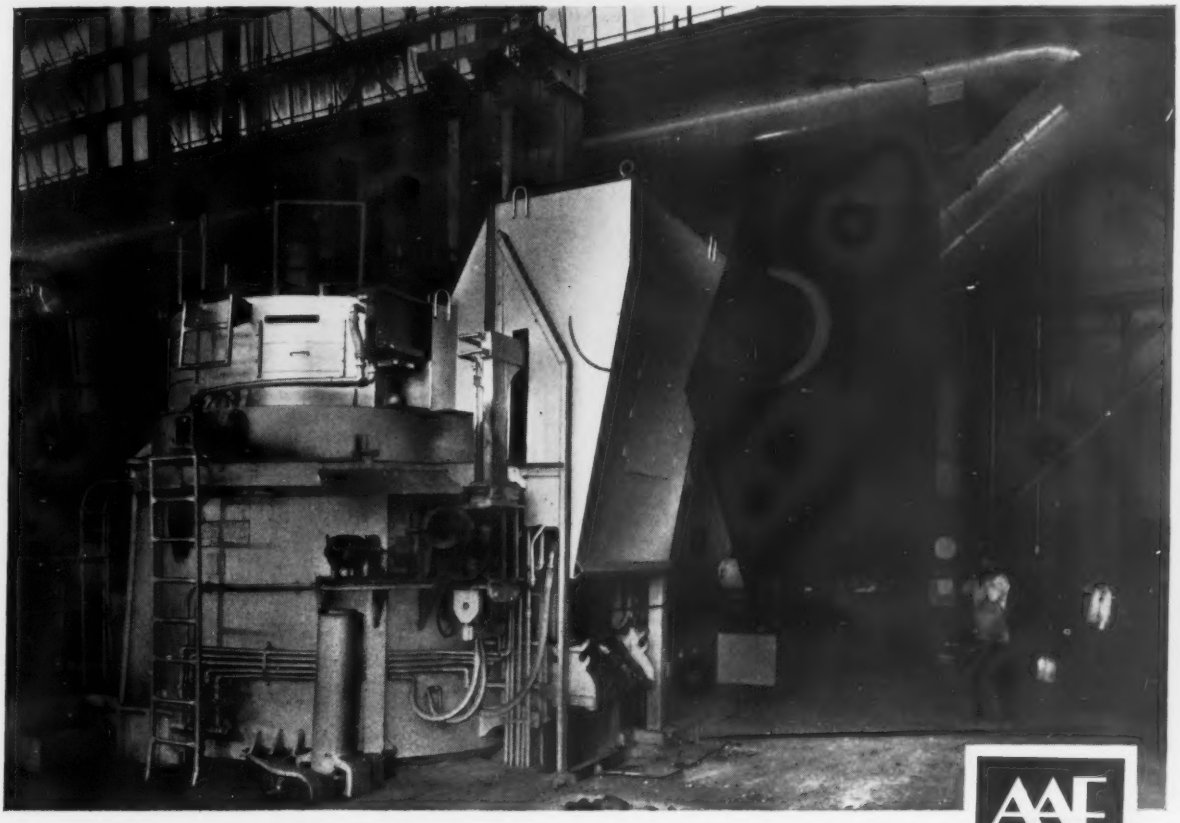

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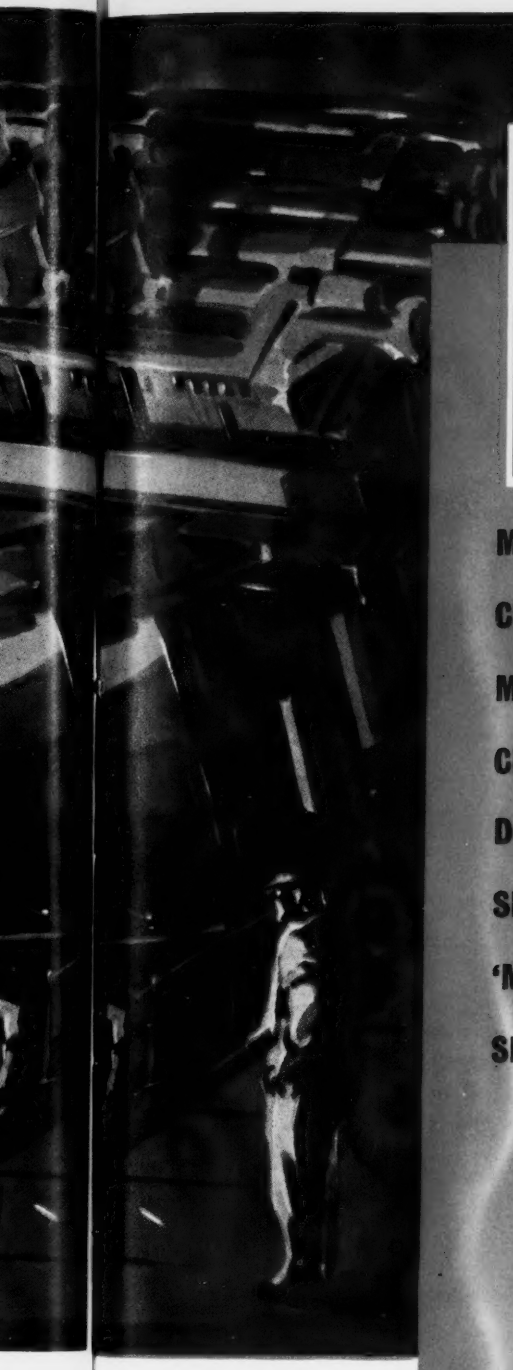

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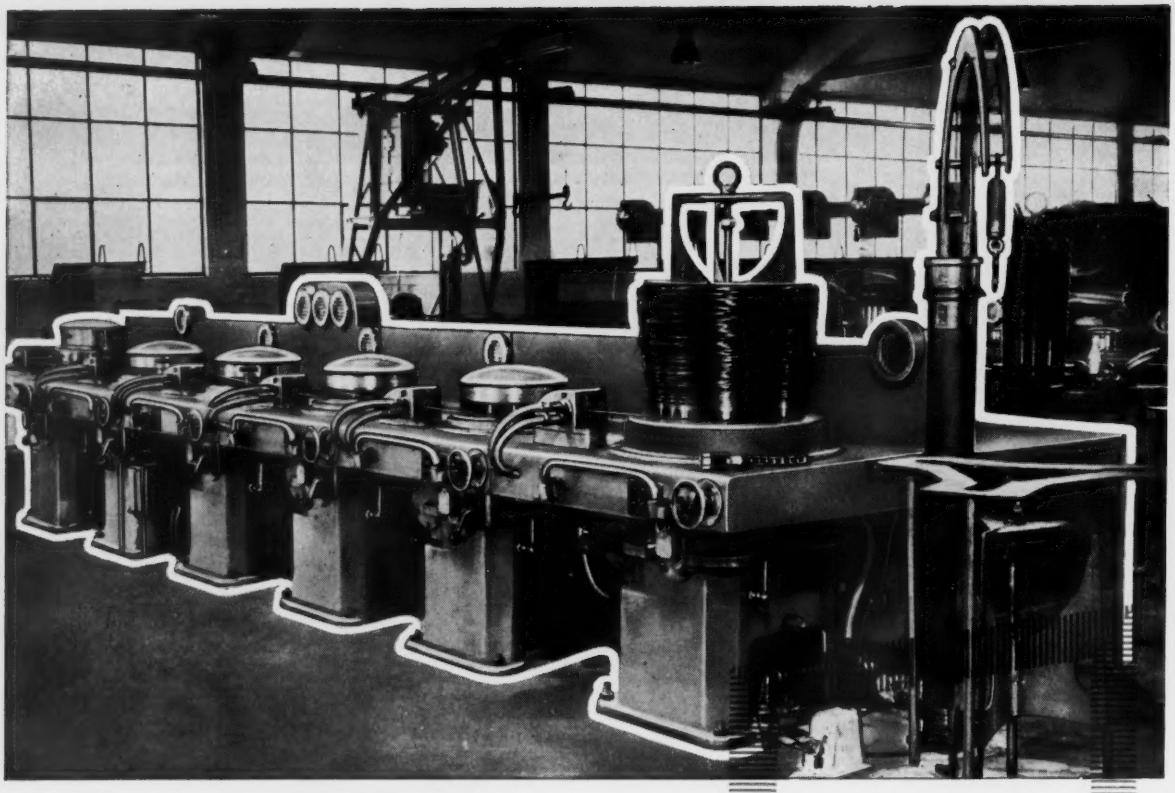

This picture shows a Beeline DG 4, built for an inlet wire diameter of about 7 mm (approx. 2 SWG). High carbon steel.

THE BEELINE WIRE DRAWING MACHINE

Straight-line type Wire Drawing Machine for high production of all wire grades

Prominent Beeline features:

- Complete absence of slipping between wire and block.
- Direct block-to-block wire running, with automatic speed control and no loops or other mechanical adjusting devices.
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Let us help you to solve your problems. We shall be glad to answer your questions promptly. Don't forget to let us know what wire is to be drawn, the inlet and finished diameter, its intended use, the production required, and all other relevant information (tensile strength of the finished wire etc.). Then we can suggest a machine that will be just right for you.

The machine is at present manufactured in three different sizes:

BEELINE DG 5

for heavy wire, about 13 mm. (7/0 SWG)

BEELINE DG 4

for wire rods, about 7 mm. (2 SWG)

BEELINE DG 3

for wire with an inlet diameter of about 3 mm. (11 SWG)

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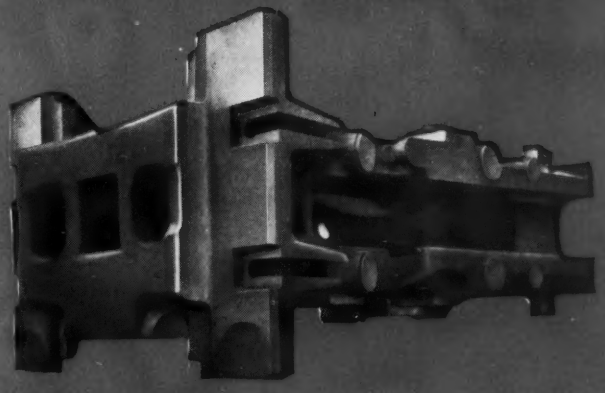

The production of forgings and castings to the large sizes demanded by present day engineering, requires machine and erection shops completely equipped to meet this need. Beardmores have extensive workshops capable of manufacturing and handling such items as roll housings and a complete rolling mill can be erected for inspection prior to despatch, a service that only a few makers can give.

The illustration shows a cast steel work roll housing during and after machining. It measures 15' 8" x 11' 6" x 8' 0" and weighed 73 tons 5 cwt. in the condition shown.

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Forgings and Castings up to 170 tons in Carbon and Alloy steels, Boiler Drums, Rolling Mill Plant, Railway Carriage and Wagon Axles, Heavy General Engineering Plant, Armaments and complete machining facilities.

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Arc Furnaces for Round Oak

As part of a major expansion scheme, Round Oak Steel Works Limited, a member of the T.I. group of companies, has ordered two Birlec Lectromelt Arc furnaces, each of 50 tons nominal capacity. Together the furnaces will add something like 170,000 ingot tons a year to the Round Oak output. The scheme is of particular importance since, in the U.K. at least, it is the first to employ electric furnaces for the tonnage production of plain carbon steels.

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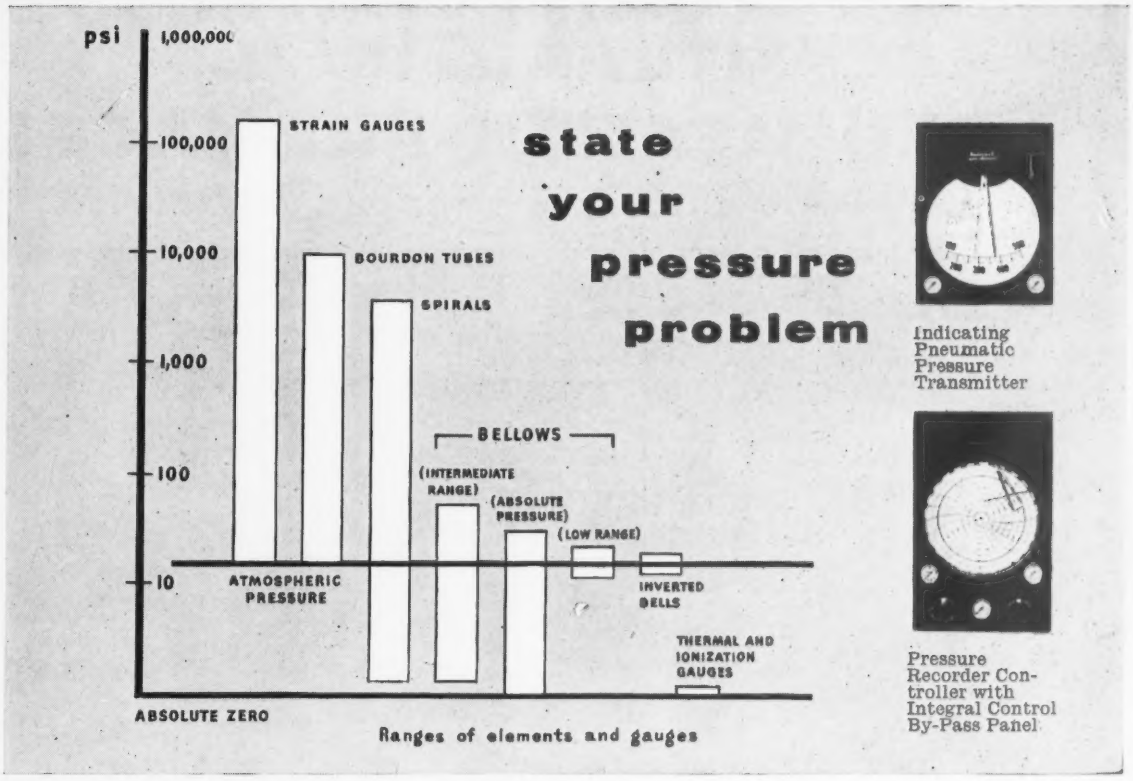


Honeywell HAS THE MEASURE OF IT

For many years the name Honeywell has been synonymous with industrial instrumentation of the highest quality and the widest possible field of application. Now the Company has extended its production programme—and its reputation for universally reliable instruments—to include a complete range of pressure and vacuum controls with many outstanding features.

Elements for every need
They include spiral, spring and bellows...low range spring and bellows...absolute pressure bellows.

Wide range of pneumatic control forms
On-off, proportional, two-term and three-term control forms are available.

Liberal overload protection
Protection from overload risk, as high as 500 per cent on some models, is a feature of all pressure elements.

Wide variety of models available
Instruments available for vacuum or pressure measurement include single, 2 and 3-pen recorders, and single and 2-pen recorder controllers.

Power and ruggedness
Elements are designed to give more than sufficient power for pen or pointer operation—guaranteeing many years of dependable service.

Pneumatic transmission
For pressure measurement on dangerous fluids, a pneumatic transmitter is available. It can be used with conventional or miniature instruments.

Engineering service
Each Honeywell instrument carries with it a technical service which extends from initial engineering recommendations to continued and successful operation.

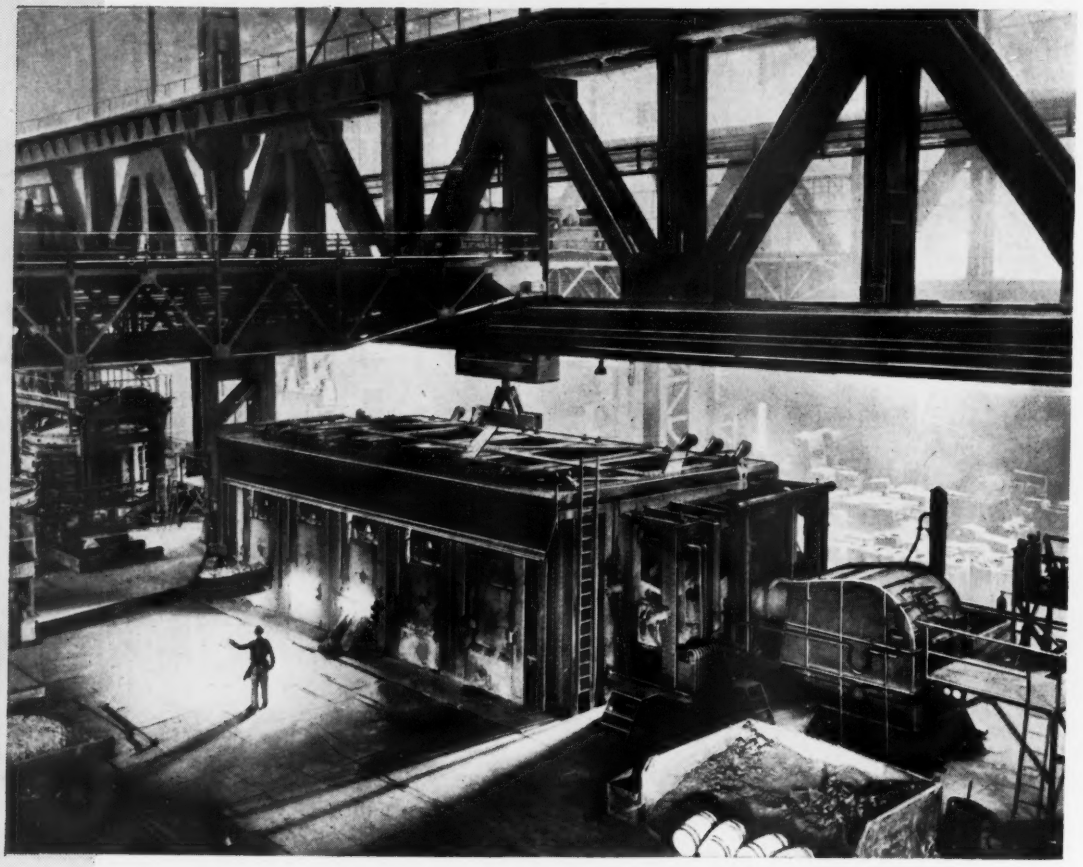
For further information (Specification Sheets 708 and 710) write to Honeywell-Brown Limited, 1 Wadsworth Road, Perivale, Greenford, Middlesex. Sales Offices located in the principal cities of Britain and Europe and throughout the world.

Honeywell
BROWN INSTRUMENTS
First in Controls

MAERZ

OPEN HEARTH FURNACES

Maerz Industrie-Ofenbau A.G. Zurich



200/250 ton Tilting Furnace, MAERZ system, for producer gas, coke-oven gas or fuel-oil firing.

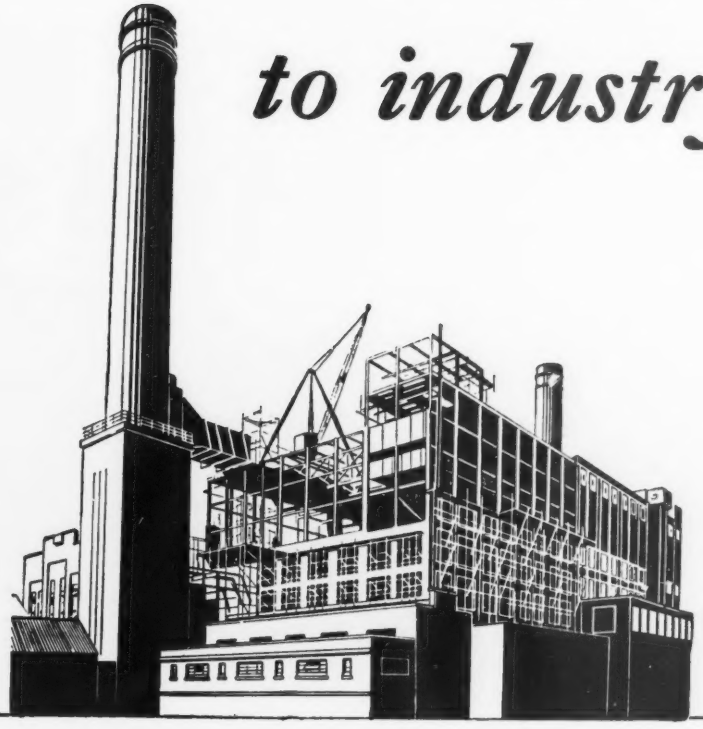
Represented in Gt. Britain by.. PRIEST

PRIEST FURNACES LIMITED · LONGLANDS · MIDDLESBROUGH

also at TELEGRAPH BUILDINGS · HIGH ST · SHEFFIELD

F98

A complete service to industry



For over thirty years Simon-Carves have played an important part in the development of economic power generation. At home and overseas Simon-Carves boiler plants are at work or in course of design and construction, ranging from small industrial units to central power station boilers rated at up to 550,000 lbs. per hour.

The co-ordination of the company's civil, mechanical and electrical engineering departments coupled with extensive research facilities enable Simon-Carves to offer an expert and comprehensive service to all users of steam power.

Complete power plant by Simon-Carves Ltd

SIMON ENGINEERING GROUP

STOCKPORT, ENGLAND

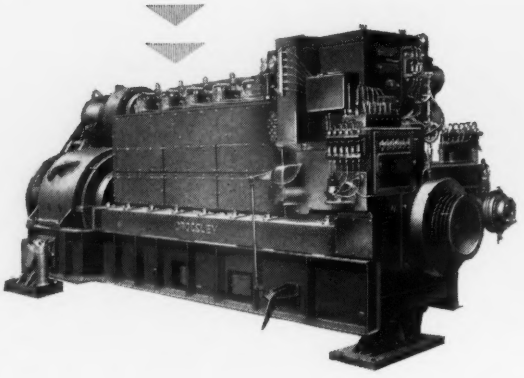
OVERSEAS COMPANIES | *Simon-Carves (Africa) (Pty) Ltd: Johannesburg* *Simon-Carves (Australia) Pty Ltd: Botany, N.S.W.*

S.C. 116

DIESEL ELECTRIC SHUNTERS

Employed with conspicuous success in large numbers of diesel-mechanical shunters, the Crossley straight-line Scavenge Pump Diesel Engine is now applied to diesel-electric operation in ten standard British Railways 0-6-0 shunting locomotives.

As prime mover of the power unit, for which Messrs Crompton Parkinson Ltd. were the main contractors, the compact six-cylinder "EST" type engine has a continuous rating of 350 b.h.p. at 825 r.p.m. and provides a maximum tractive effort of 35,000 lb.



CROSSLEY DIESEL ENGINES

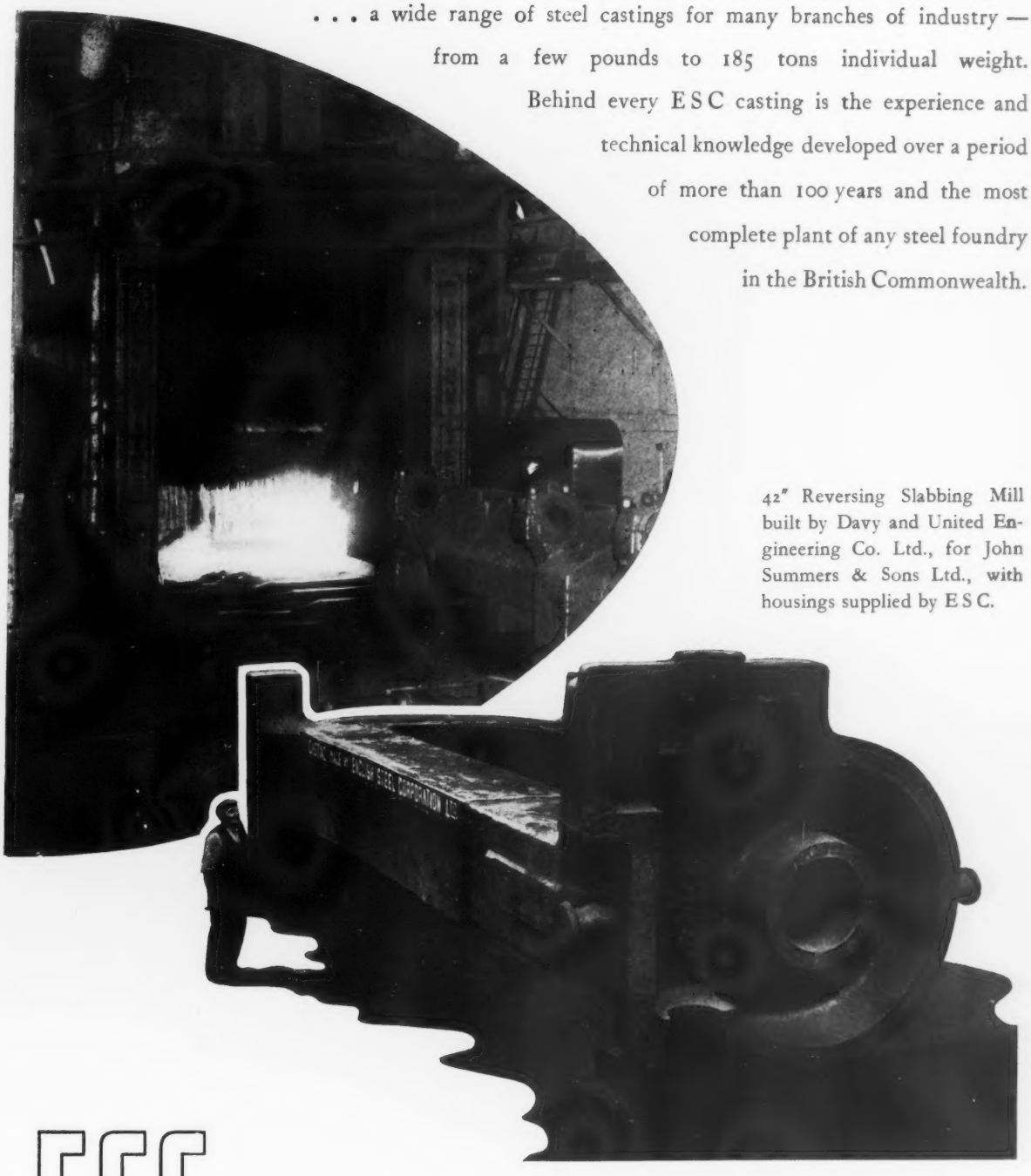
CROSSLEY BROTHERS LIMITED · OPENSHAW · MANCHESTER 11.

LONDON OFFICE: Langham House, 308 Regent Street W.1

C.194

The ESC foundry produces . . .

. . . a wide range of steel castings for many branches of industry — from a few pounds to 185 tons individual weight. Behind every ESC casting is the experience and technical knowledge developed over a period of more than 100 years and the most complete plant of any steel foundry in the British Commonwealth.



42" Reversing Slabbing Mill built by Davy and United Engineering Co. Ltd., for John Summers & Sons Ltd., with housings supplied by ESC.

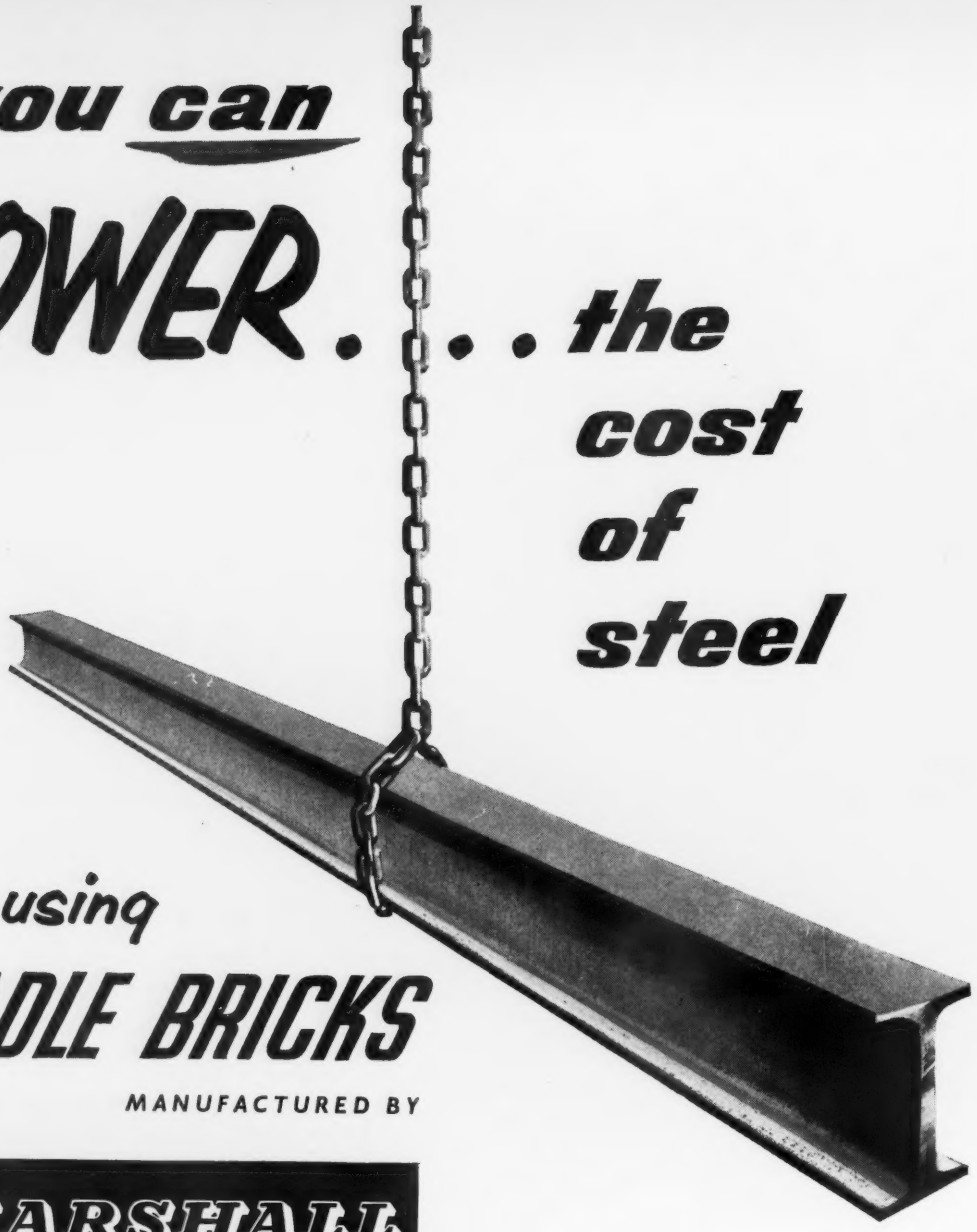
ESC
SHEFFIELD

ENGLISH STEEL CASTINGS CORPORATION LTD.

River Don Works · Sheffield.

A WHOLLY OWNED SUBSIDIARY OF ENGLISH STEEL CORPORATION LTD.

you can LOWER . . . the cost of steel



by using

LADLE BRICKS

MANUFACTURED BY

MARSHALL

FOR FURTHER INFORMATION
WRITE TO:-

THOMAS MARSHALL & CO. (LOXLEY) LTD. *STORRS BRIDGE WORKS, LOXLEY, NR. SHEFFIELD* *TELEPHONE 43844-5*

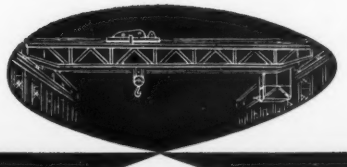
T.M.30

JOSEPH ADAMSON

Electric Overhead Travelling Cranes

JAC

All Joseph Adamson electric overhead travelling cranes are built to give unfailing service under the most exacting conditions. Generous proportions, provision for easy maintenance and the special attention given to operator control and safety measures are features of Joseph Adamson cranes. Electric overhead travelling cranes can be supplied to all specifications, including cranes suited to the most exacting 24 hours-a-day process work.



JOSEPH ADAMSON & CO. LTD.

P. O. BOX 4 · HYDE · CHESHIRE

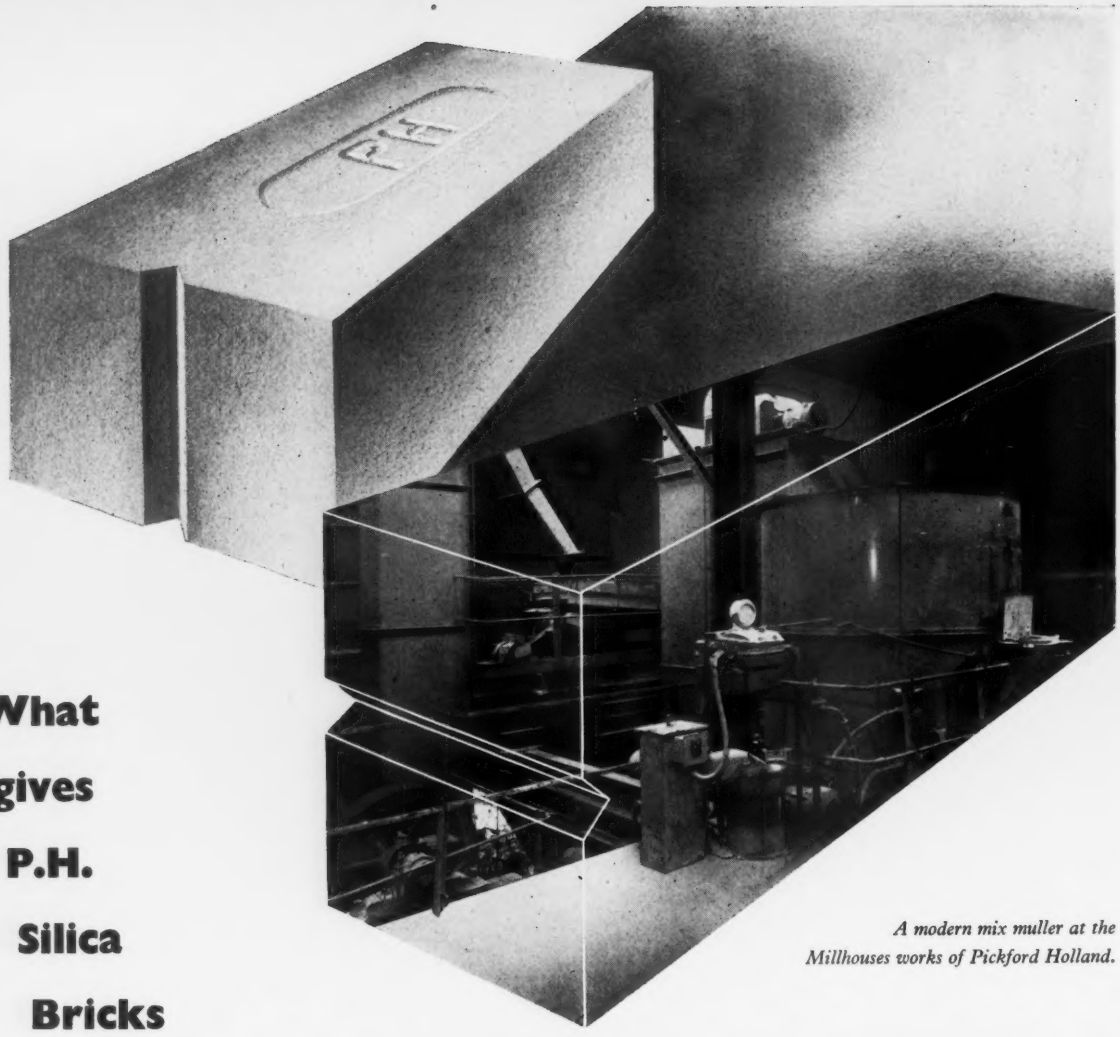
in association with

Adamson Alliance Co. Ltd., 165 Fenchurch St., London, E.C.3

The Horsehay Company Ltd., Wellington, Shropshire

THE ADAMSON GROUP

JA. 12



A modern mix muller at the Millhouses works of Pickford Holland.

What gives P.H. Silica Bricks their superb lasting properties?

An ounce here, a few degrees there, can make or mar the production of a successful and efficient refractory brick.

Pickford Holland have equipped their works with plant as up-to-date as any in the country, so that all production processes are carefully regulated to the finest limits. Careful control results in exact specifications being maintained, both of actual quantities forming the "mix" and the subsequent temperatures at which it is fired.

Illustrated is part of the modern plant producing silica bricks of the highest quality for Pickford Holland. Here the raw materials are crushed, graded and mixed under close technical supervision. The rigid control exercised at this stage is an essential factor in the production of refractory materials conforming to the high standards of Pickford Holland.

PICKFORD HOLLAND *Silica Bricks*

Consistent in Size, Shape, Texture and Performance

PICKFORD HOLLAND & CO. LTD., 381 FULWOOD ROAD, SHEFFIELD 10

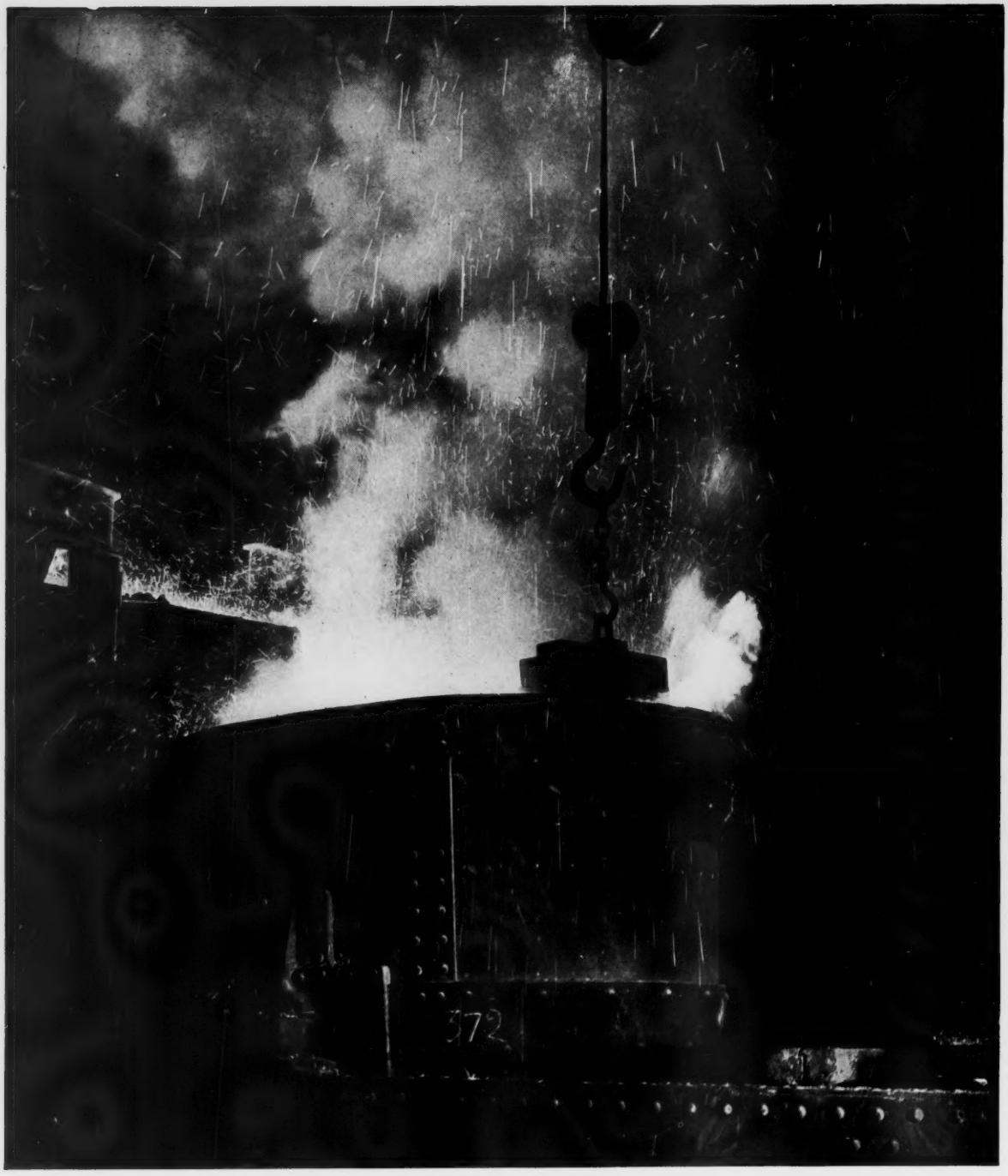
Coal blending for carbonisation at John Summers & Sons Ltd., Shotton, Flint, by the Robins-Messiter system.
This most efficient system has already been widely applied to the blending of ores.

FRASER & CHALMERS

FRASER & CHALMERS ENGINEERING WORKS
ERITH · KENT

THE GENERAL ELECTRIC CO. LTD., OF ENGLAND

FC52A

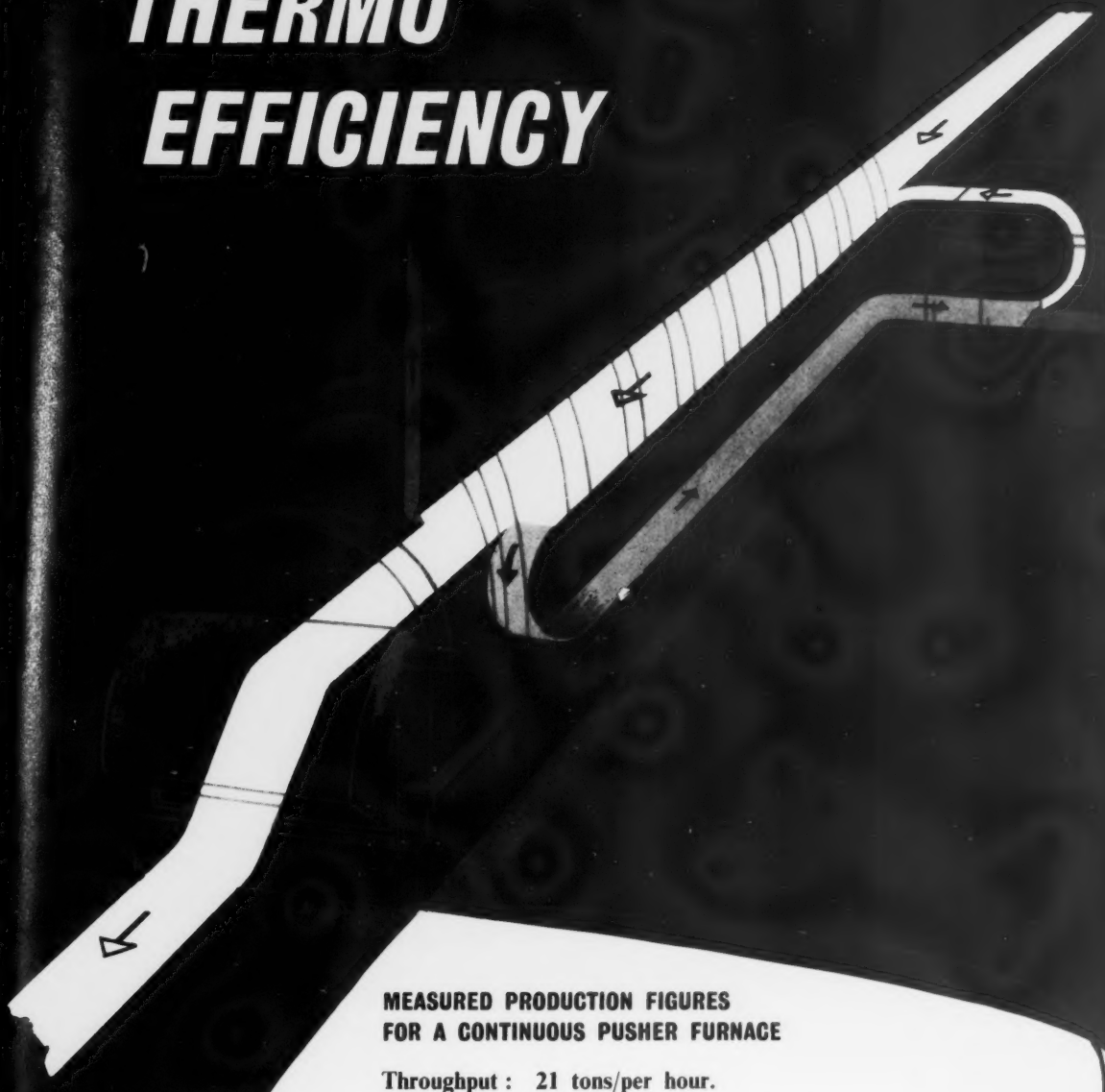


BROWN BAYLEY STEELS LIMITED

TRADE BROWN BAYLEY'S MARK SHEFFIELD 9

TELEGRAMS: BAYLEY SHEFFIELD 9 • TELEPHONE : SHEFFIELD 41031

THERMO EFFICIENCY



MEASURED PRODUCTION FIGURES FOR A CONTINUOUS PUSHER FURNACE

Throughput : 21 tons/per hour.
Charge : Ingots 220 mm. sq.
Fuel : Coke Oven Gas 450 B.Th.U./c.ft.
Heat Consumption : 520 B.Th.U./lb.
Scale loss : 1%
Wall and door loss : 5%

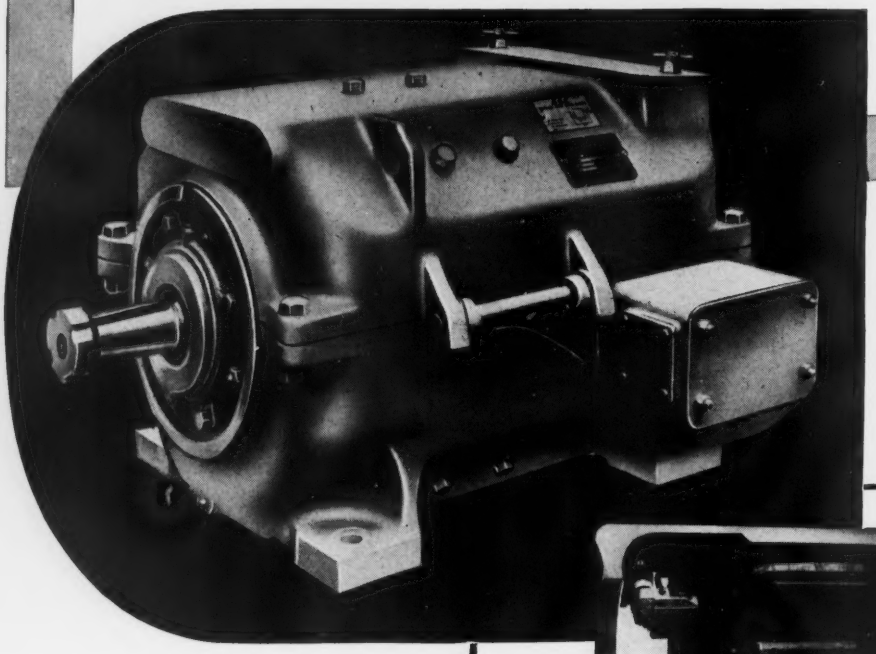
furnace efficiency 73%

Thermo

GIBBONS-THERMO

GIBBONS BROTHERS LIMITED. P.O. BOX 19. DIBDALE. DUDLEY. WORCS.
Telephone: Dudley 3141 Telegrams: GIBBONS. DUDLEY

STEELWORKS D.C. MOTORS



A typical G.E.C. direct current steelworks motor.

A G.E.C. direct current steelworks motor with top half of shell swung open.

G.E.C. steelworks motors are available from 5 h.p. to 200 h.p. and comply fully with the dimensions and ratings standardised by the American Association of Iron & Steel Electrical Engineers.

The motors are of extremely robust construction and are specially designed for quick starting, stopping and reversing.

Ask for Technical Descriptions Nos. 362 and 419.

G.E.C.

THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, LONDON, W.C.2

Why Red Lead?

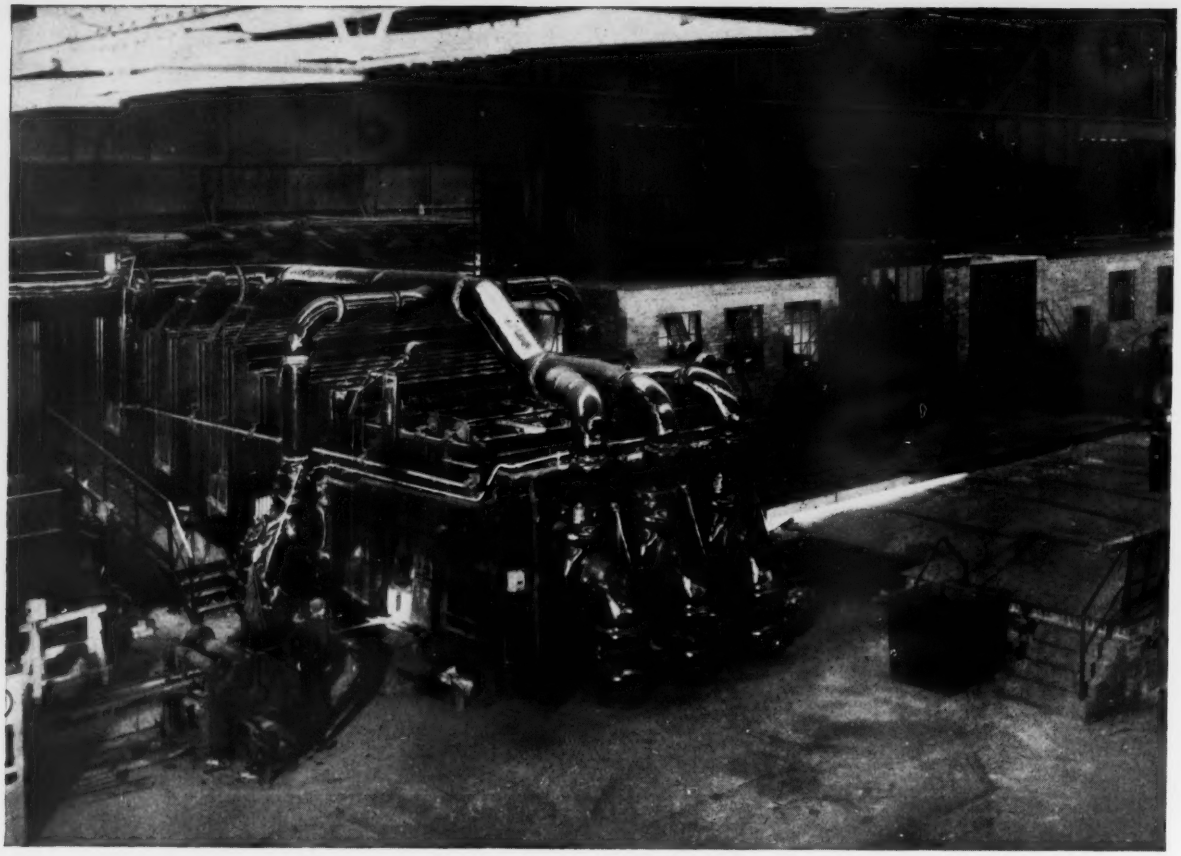
WE BELIEVE that the cost of priming ferrous metal with genuine Red Lead is too high for the competitive world we live in today. Especially when there is an alternative readily available which will preserve the metal equally well at a much lower initial cost and possessing other important advantages. "Superlative" Metal Primer is based on Lead Cyanamide, a pigment possessing unusual Corrosion-inhibiting properties; it does not set or settle and is easily stirred, even after long storage; it can be applied quickly without fatigue, can usually be overcoated within 24 hours and a gallon covers approximately twice the area as compared with genuine red lead. This combination of saving in paint and labour cost is vital, owing to the economic necessity for low costs. "Superlative" Metal Primer is put forward as a proposition worthy of serious consideration by all who are interested in lowering maintenance costs with reasonable safeguards.

"Superlative" METAL PRIMER

prevents Corrosion Economically

BRITISH PAINTS LIMITED

Portland Road, Newcastle upon Tyne, 2. Tel. 25151 · London: Crewe House, Curzon Street, W.1. Tel. Grosvenor 6401-5.



CONTINUOUS BILLET REHEATING FURNACE WITH TYPHOON BURNERS

TYPHOON

ROTARY FLAME GAS BURNERS

TYPHOON GAS BURNERS ENSURE INTIMATE MIXTURE OF GAS AND AIR · THE ABSOLUTE MINIMUM OF SPACE · HIGHEST POSSIBLE FLAME TEMPERATURE · ACCURATE REGULATION AND ABSOLUTE CONTROL OF FURNACE ATMOSPHERE · INCREASED OUTPUT WITH LESS FUEL

Equally suitable for crude producer gas, blast furnace, coke oven, mixed or town gas

OTHER SPECIALITIES

MORGAN GAS MACHINES · SOAKING PITS (Isley Controlled) · MILL FURNACES "ARCA" GAS PRESSURE REGULATORS HOT METAL MIXER CARS · MORGAN AIR-JECTORS · NASSHEUER CONTINUOUS BRIGHT ANNEALING FURNACES

(Sole Licensees)

THE INTERNATIONAL CONSTRUCTION CO. LTD.

(Successors to Julian Kennedy, Sahlin & Co., Ltd.)

56 KINGSWAY · LONDON · W.C.2

Telephone: HOLBORN 1871-2

Telegrams: SAHLIN, WESTCENT, 2 LONDON

Breaking fresh ground

You can see the immense possibilities of this project. No one has ever delved—or indeed spun—here before. It's virgin soil. Your difficulty lies in choosing just the right material to stand up to what you know will be exacting conditions. It is here that the technical knowledge of our metallurgists can help you break fresh ground. They have wide experience in the working, manufacture and use of nickel, nickel alloys and nickel-containing materials and may be able to suggest just the metal for your purpose. In our laboratories tests can be carried out to determine the behaviour of any nickel-containing material and the work of developing something new never ceases. Many major engineering developments have resulted from this research.
Make full use of our services.

THE MOND NICKEL COMPANY LIMITED
THAMES HOUSE · MILLBANK · LONDON · SW1

TGA GN17

Newells PROVED MACHINES FOR MODERN Sinter Plants

A battery of four Newells patented Rod Mills in operation at Appleby-Frodingham Steelworks (third repeat order).

PATENTED Rod Mills

for producing
Fine Crushed Coke

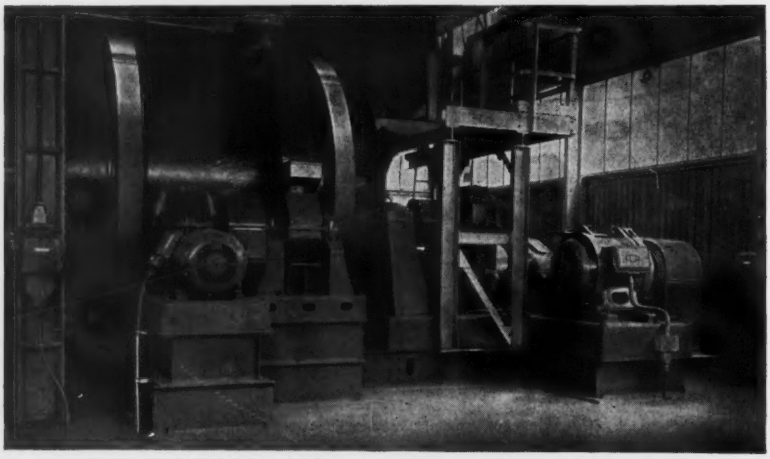
- Uniformly graded coke of constant fineness essential for making first class sinter.
- Crushes breeze containing up to 16% moisture.
- No predrying necessary.
- Reliable operation with lowest overall maintenance costs.
- Proved by continuous service since 1938 in seven leading British Steelworks.

A battery of nine Newells Feed Tables in operation at a Steelworks Sinter Plant.

HEAVY DUTY Feed Tables

for handling
Ore & Sinter Fines, Coke, Mill Scale and Flue Dust

- Very reliable in operation.
- Very low maintenance costs.
- Proved by continuous operation in British Steel works since 1938.
- We have supplied 37 Feed Tables for different sinter plants at Messrs. Appleby-Frodingham Steel Company.



One of 12 Newells patented Mixers in operation at Appleby-Frodingham Steelworks

PATENTED COMBINED Drum and Paddle Mixers

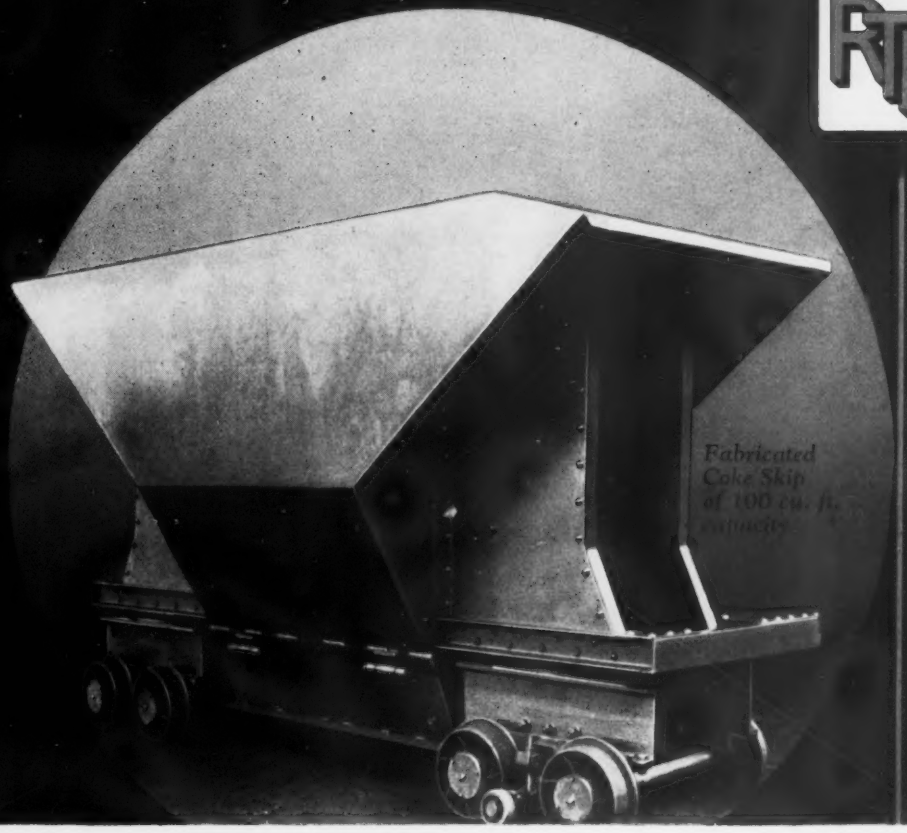
for mixing
Ore & Sinter Fines, Coke, Mill Scale, Flue Dust and Water

- Intensive, thorough and uniform mixing of solids and water unobtainable by any other machine.
- Efficient mixing is a primary necessity for the manufacture of first class sinter.
- Made in units up to 300 tons per hour continuous capacity.
- Proved by continuous operation in British Steel works since 1938.

ERNEST NEWELL AND COMPANY LIMITED, MISTERTON VIA DONCASTER, ENGLAND

Designers and Manufacturers of CALCINING, DRYING, GRINDING, CRUSHING, MIXING and HANDLING PLANT FOR STEELWORKS. *Telegrams:* Newells, Misterton, Notts., Eng

FOUNDRY AND ENGINEERING SERVICE FOR INDUSTRY



IN addition to our wide range of foundry work, we are constantly engaged in the fabrication of steel platework by the most modern methods, often combined with components produced in our fine machine shops.

We specialize particularly in equipment for the steel and other heavy industries, and our products will be found in some of the most up-to-date plants in this country.

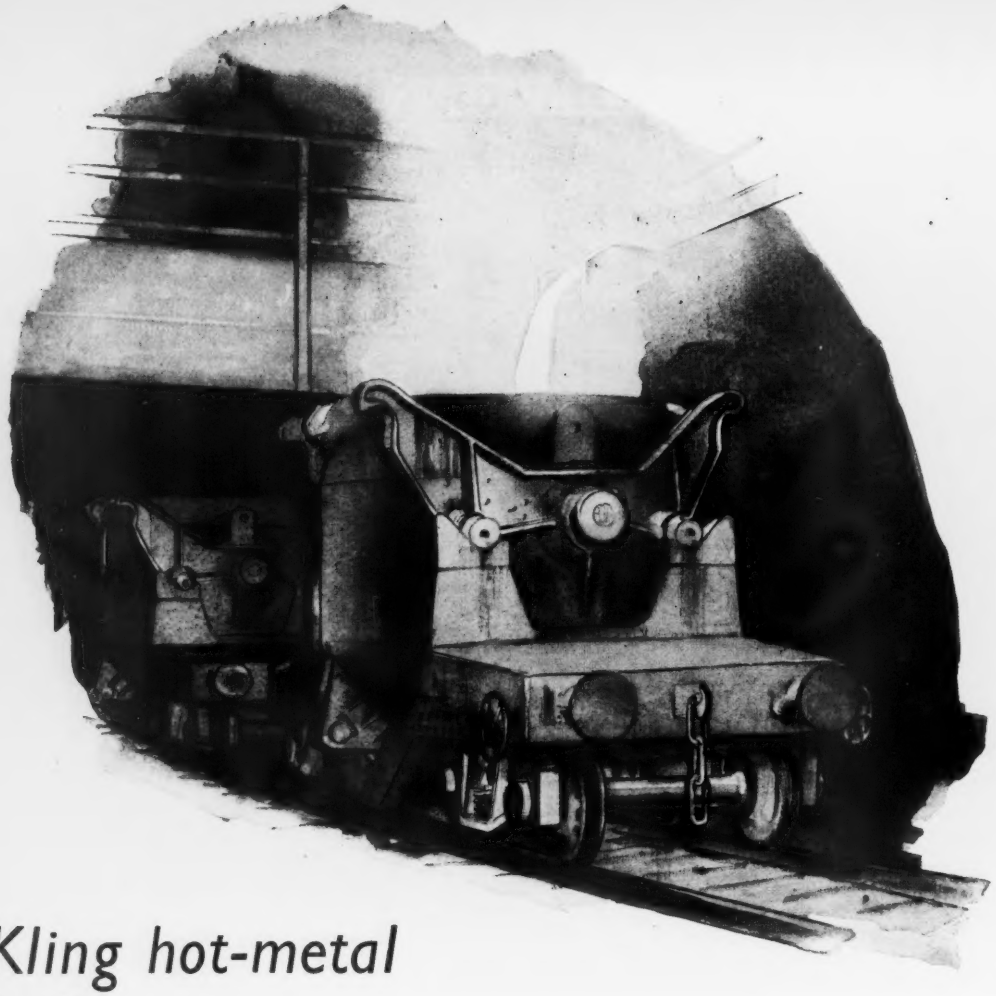
SOME OF THE PRODUCTS OF THE MACHYNYS AND LANDORE WORKS

CARBON STEEL CASTINGS of all classes up to 12 tons for any one casting. ROLLS—Cast iron and spheroidal graphite (*S.G. Iron*) up to 10 tons; steel rolls up to 10 tons. TABLE, LOOPER AND COILER ROLLERS, ETC., in molybdenum, chrome and nickel, cast iron alloy, spheroidal graphite (*S.G. Iron*). SPHEROIDAL GRAPHITE—special duty and general engineering castings, various types up to 12 tons. GENERAL GREY IRON CASTINGS—Up to 10 tons. INGOT MOULDS—from 5 cwt. to 30 tons. SLAG LADLE BOWLS—Up to 30 tons. NON-FERROUS—All types of brass and phosphor bronze, etc. PATTERNS—Capacity for all types. STEEL CONSTRUCTIONAL, FABRICATING AND GENERAL REPAIR WORK—All types of fabrication of mild and alloy steels up to 25 tons in weight. ANNEALING COVERS—Mild steel, both electrically welded and riveted for sheet and tinplate works. Fabricated stainless steel covers for coil annealing. MACHINE AND ERECTING SHOPS—Machines and borers capable of work to 8 ft. dia., planing within a range of 20 ft. long × 5 ft. wide × 5 ft. high. SPUR WHEELS, GEAR WHEELS, PINIONS, in cast steel, fabrication or S.G. Iron.

RICHARD THOMAS & BALDWINS LIMITED

FOUNDRY & ENGINEERING PRODUCTS COMMERCIAL DEPARTMENT DIVISION J, BANK BUILDINGS, CASTLE SQUARE, SWANSEA, GLAM. Telephone SWANSEA 55885.

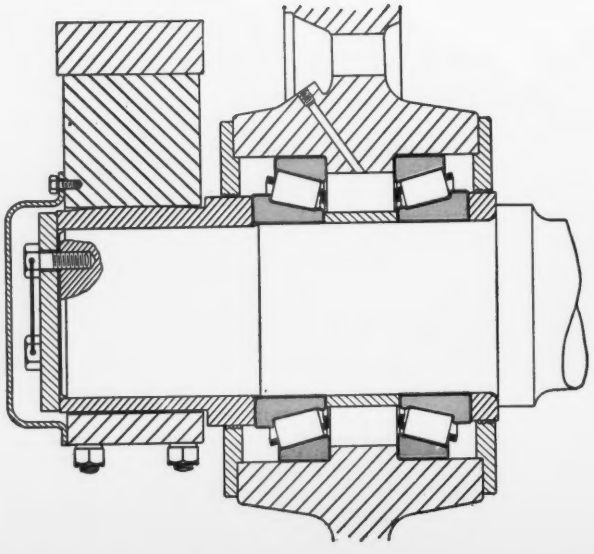
We will be pleased to send an experienced member of our technical liaison engineering staff to discuss any technical matter with prospective users of our products.



Kling hot-metal ladle cars

The 75-ton hot-metal ladle cars shown in service at the Sheepbridge Company Ltd., Chesterfield, are made by Ashmore, Benson, Pease and Company Ltd.

The wheels run on Timken tapered-roller bearings, as shown in the line drawing, and over 80 cars, built and building by the firm, are equipped in this way.



MADE IN ENGLAND

TIMKEN

tapered-roller bearings

REGD. TRADE MARK: TIMKEN

BRITISH TIMKEN LTD.

DUSTON, NORTHAMPTON; AND BIRMINGHAM

Telephone: Northampton 4921 (10 lines), Telex No. 31-620

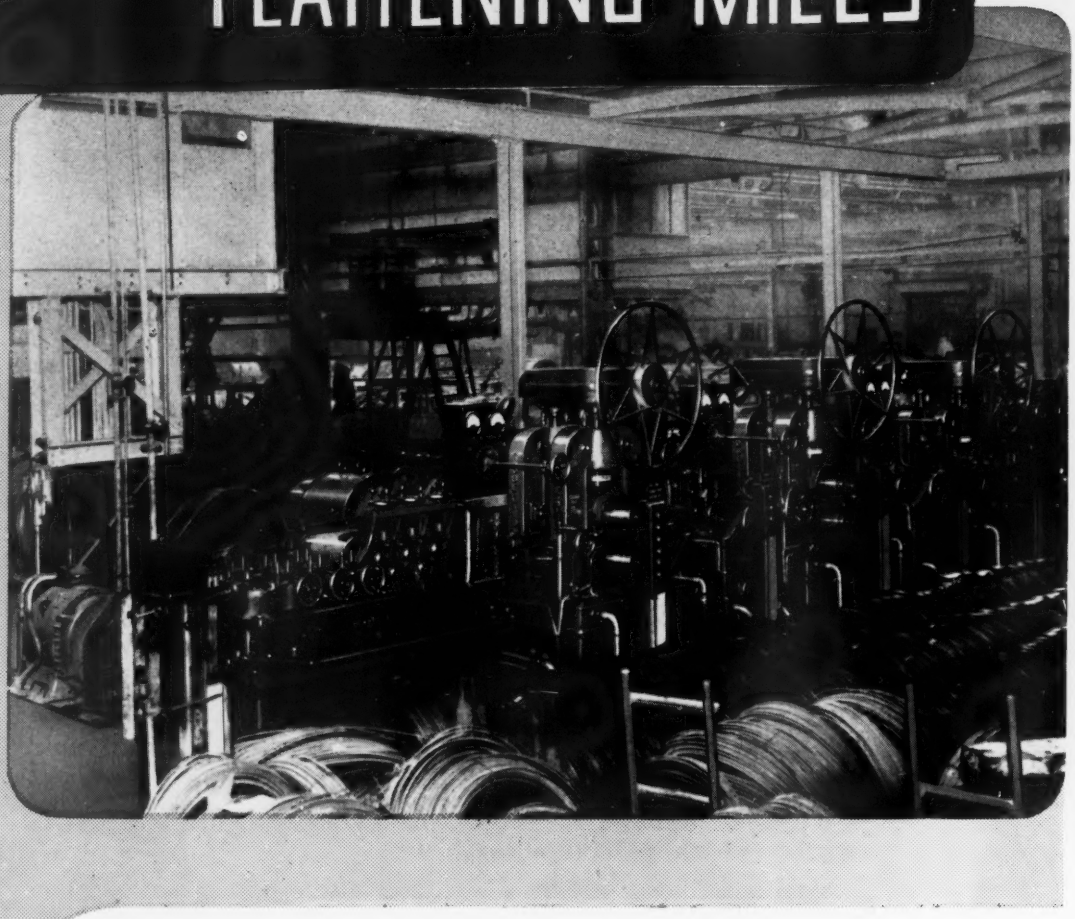
Telegrams: Britimken Northampton Telex

Subsidiary Companies: Fischer Bearings Co. Ltd., Wolverhampton
Timken-Fischer Stockists Ltd., Birmingham

THE TORCH OF INDUSTRY
NEW! the BEAGLE
A transportable profiler that cuts constant angle bevels automatically on curves of any radii
You can carry the Beagle—all up weight 125 lb.—to the job and set it up to cut in a few minutes. Electrically driven and guided by a hand steering tracing wheel, it will cut any profile in steel up to 2" thick, operating direct from working drawings with the greatest accuracy. No waiting for the work to come to the machine—no templates needed. And the Beagle is fitted with a unique cutter which will maintain any bevel up to 45° round any profile.
BRITISH OXYGEN
British Oxygen Gases Ltd., Industrial Division, Bridgewater House, St. James's, London, S.W.1.

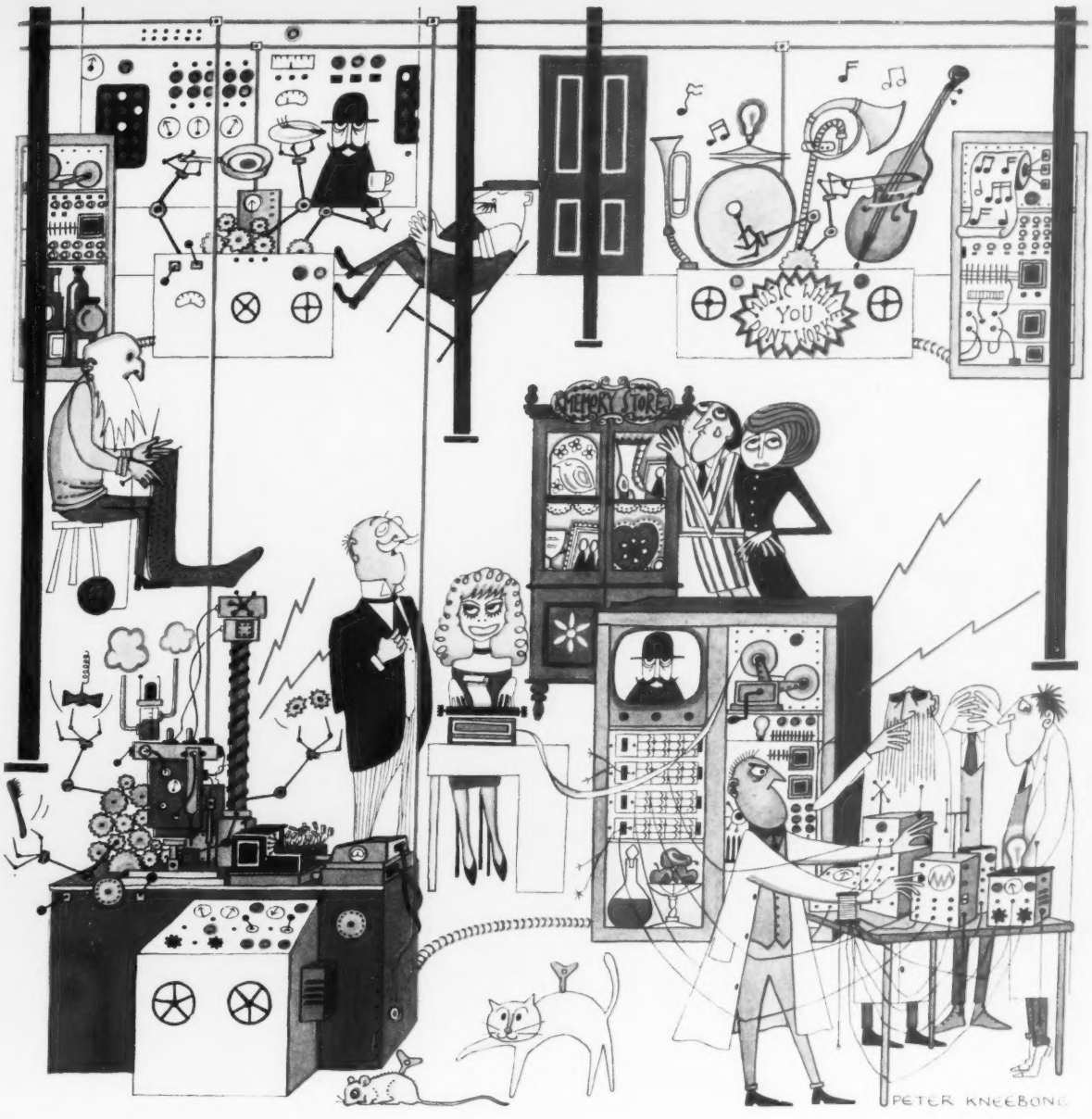
ROBERTSON

Wire FLATTENING MILLS



We illustrate above a five-stand Tandem Wire Flattening Mill for the production of nut flats and similar sections from rod up to $\frac{3}{4}''$ diameter.

W. H. A. ROBERTSON & CO. LTD., BEDFORD, ENGLAND



Oiling the wheels of industry–

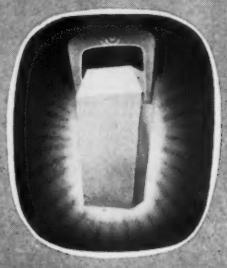
AUTOMATION IN INDUSTRY

For every modern industrial process there is a specialised grade of Sea Shell Lubricant.

SHELL

leadership in lubrication

Copies of this advertisement (in colour) can be obtained from Shell-Mex and B.P. Ltd.



for

STEELS

of

QUALITY & RELIABILITY

specify

COLVILLES LTD

195 WEST GEORGE STREET • GLASGOW C2

COKE OVEN PLANT

and by-product plant

POWELL DUFFRYN-COPPEE LIMITED

8 GREAT TOWER STREET · LONDON · EC3

MANSION HOUSE 4555

World Famous Plant

AUTOMATIC BLAST FURNACE CONTROL

FOR NO. 4 BLAST FURNACE
OF THE
STEEL COMPANY OF WALES
THE LARGEST FURNACE
IN EUROPE
WITH
25,000 CFM BURNERS

- UP TO 10% GAS SAVING
- COMPLETE REVERSAL IN A FEW SECONDS
- FULLY INTERLOCKED SEQUENCE
- ONE MAN CAN OPERATE UP TO 5 FURNACES

ZIMMERMANN &JANSEN GMBH
DUEREN/RHLD GERMANY

REPRESENTATIVES IN GREAT BRITAIN AND IRELAND
D.M.M. (MACHINERY) LTD.
LONDON S.W.1.
TELEPHONE: VIC. 6565
TELEX: GB · LN · 8071

'dag' COLLOIDAL GRAPHITE...

lubrication for high temperature processes

'dag' colloidal graphite applied to extrusion dies provides a thin, dry graphite film which ensures smooth working and improves the surface finish of the extruded metal. 'dag' colloidal graphite is strongly adherent and is unaffected by extremes of pressure or temperature. Detailed information on extrusion die lubrication is available on request.

Illustration shows 'dag' colloidal graphite being applied to the dies of a 2,000 ton horizontal extrusion press.

(photograph by courtesy of The Yorkshire Copper Works Ltd.)

dag
ACHESON TRADE MARK
DISPERSIONS

ACHESON COLLOIDS LIMITED

18 PALL MALL · LONDON · S.W.1

Telephone: WHI 2034-9 · *Telegrams:* OILDAG · PICCY · LONDON
Also ACHESON COLLOIDS COMPANY · Port Huron · Michigan · U.S.A.

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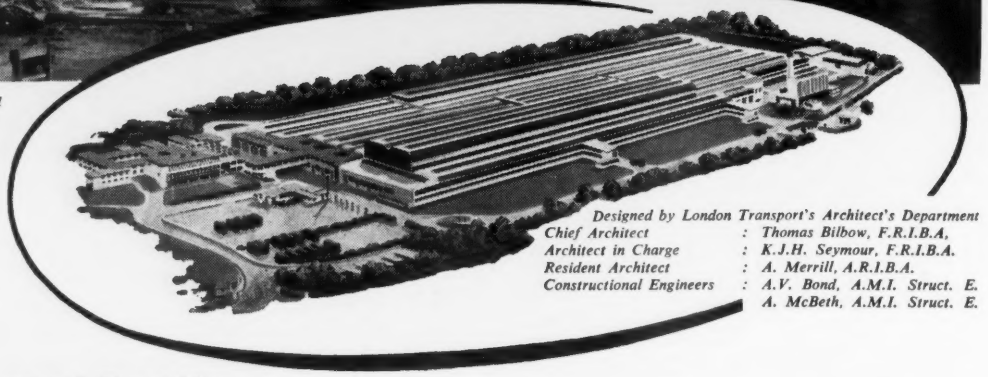

Designed by London Transport's Architect's Department

Chief Architect	:	*Thomas Bilbow, F.R.I.B.A.*
Architect in Charge	:	*K.J.H. Seymour, F.R.I.B.A.*
Resident Architect	:	*A. Merrill, A.R.I.B.A.*
Constructional Engineers	:	*A.V. Bond, A.M.I. Struct. E.*
		A. McBeth, A.M.I. Struct. E.

London Transport Executive

ROAD SERVICES FACTORY AT ALDENHAM

In this important contract, 3,600 tons of Structural Steelwork were fabricated and erected by South Durham Steel & Iron Co. Ltd.

The contract comprises the Main Workshops Buildings, together with the Main Office Block, which is connected by a bridge to the Main Workshops Buildings. Overall dimensions, approximately 1,500 ft. x 560 ft., together with various Ancillary Buildings including Boiler House, Welfare Block, Materials Store and Service Block.

SOUTH DURHAM STEEL & IRON CO. LTD.

(Incorporating CARGO FLEET IRON CO. LTD.)

Central Constructional Department, Malleable Works, STOCKTON-ON-TEES, Co. Durham.

Telephone: Stockton-on-Tees 66117.

The heat joins the flow

Electric heat can be applied wherever it's possible to bring a pair of wires. You can bring it right into the smooth flow of the production line. You can lay out your plant as you think best and install your process heating to suit the lay-out.

Electro-heat is economical. There's no wastage at all. It gives the appropriate *kind* of heating, at the right temperature for as long, or as short a time, as you need. It can be controlled exactly, easily; better still, automatically.

It's quick, it's compact. The equipment is light, neat, simple. It's clean. It saves overheads in many directions. With electro-heat you get higher production, lower costs and better working conditions.

Electricity for Productivity

Ask your ELECTRICITY BOARD for advice and information, or get in touch with E.D.A. They can lend you, without charge, films about the uses of electricity in industry. E.D.A. are also publishing a series of books on Electricity and Productivity. Titles now available are: Resistance Heating, Electric Motors and Controls, Higher Production, Lighting, and Materials Handling. Price 8/6, or 9/- post free.

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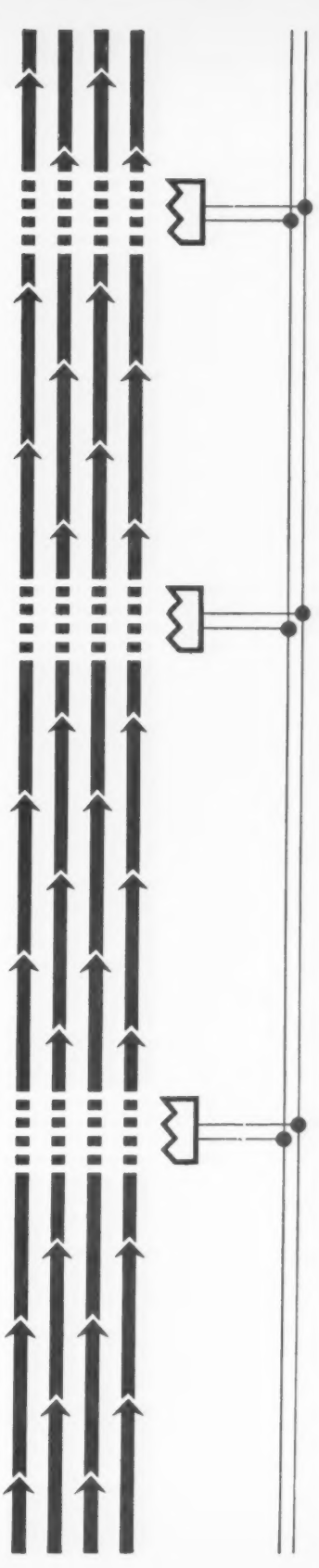
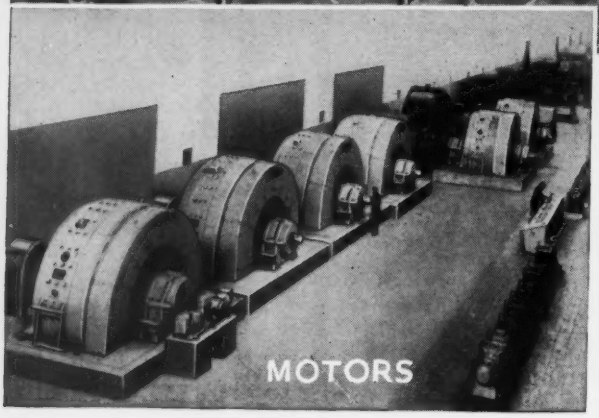


Rolling Mill Equipment

Pumpless Steel-tank Mercury-arc Rectifiers



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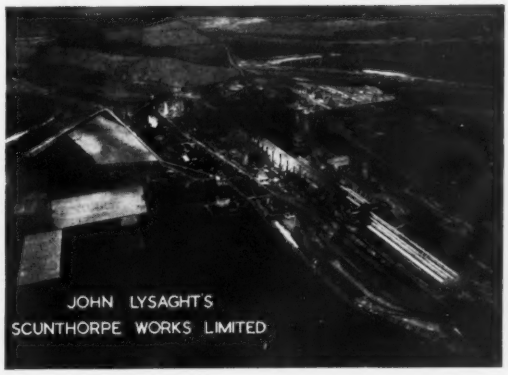

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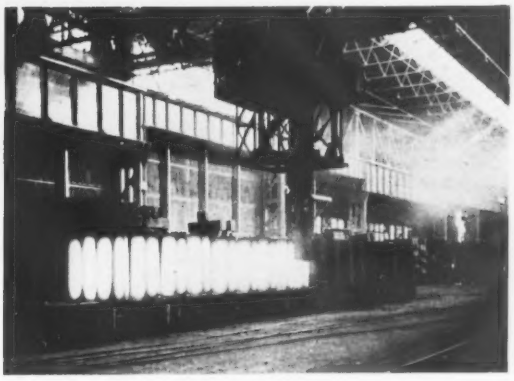

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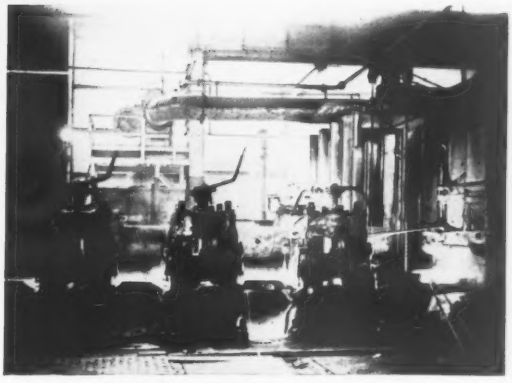

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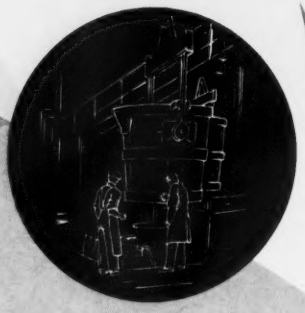

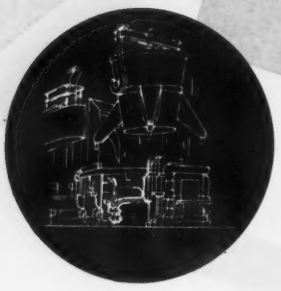

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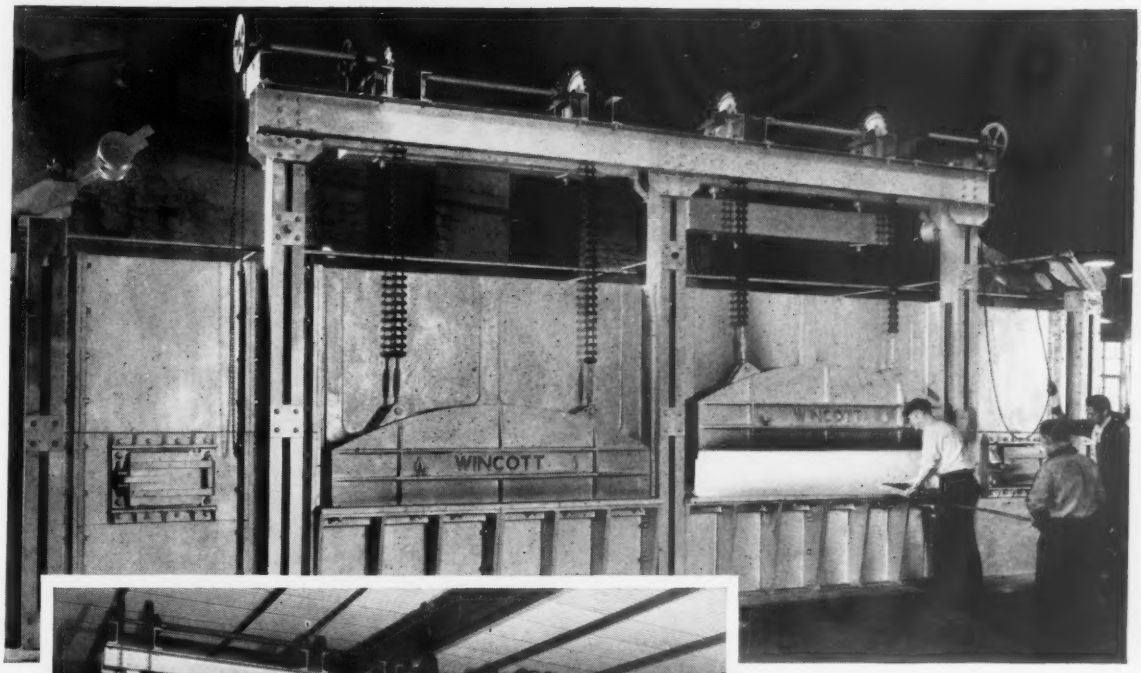

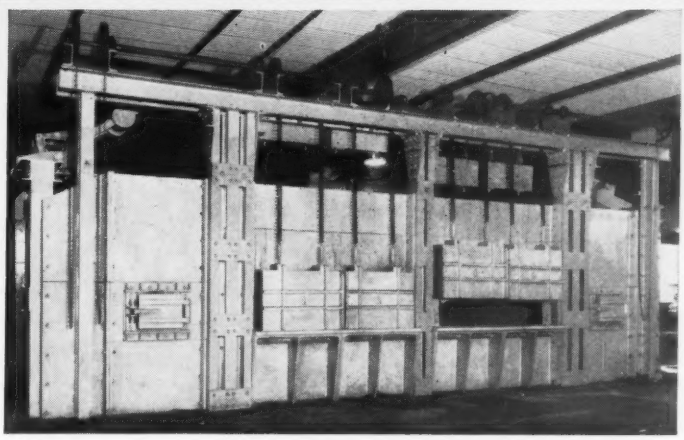

Above is a twin furnace with hearths 8′ 0″ wide by 9′ 0″ long, each fitted with a single door.
To the left is a twin furnace with hearths 6′ 0″ wide by 8′ 0″ long, each fitted with double doors.

Photographs by courtesy of Messrs. Darwins Ltd.

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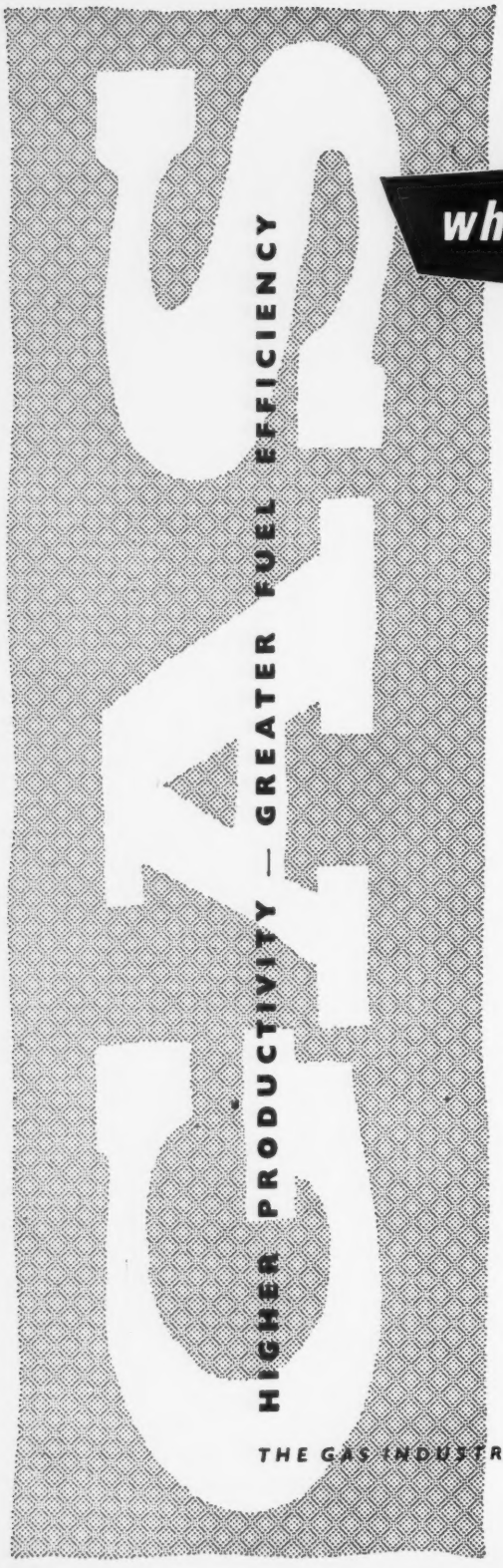

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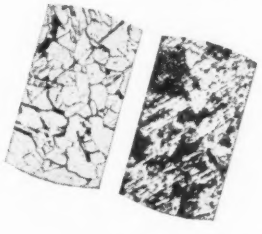

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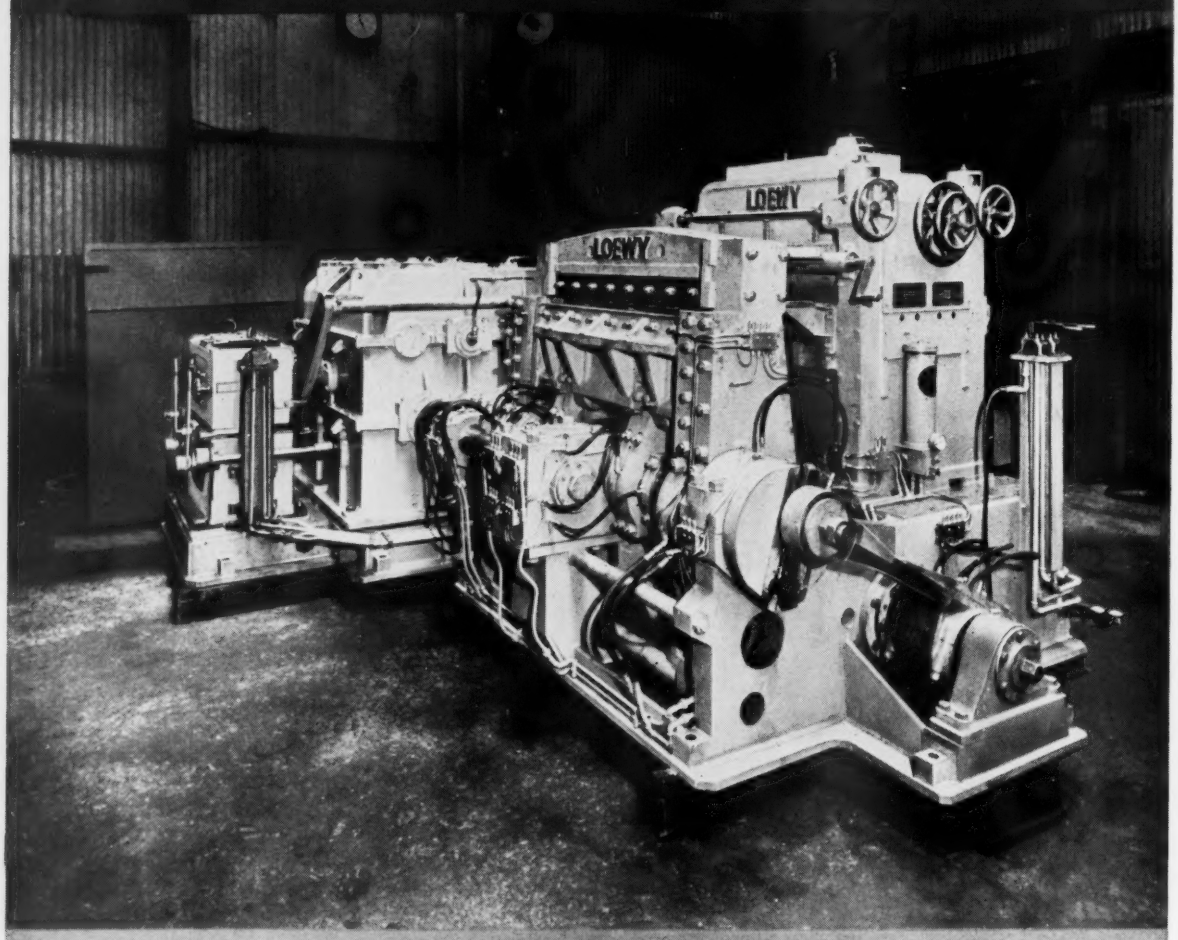

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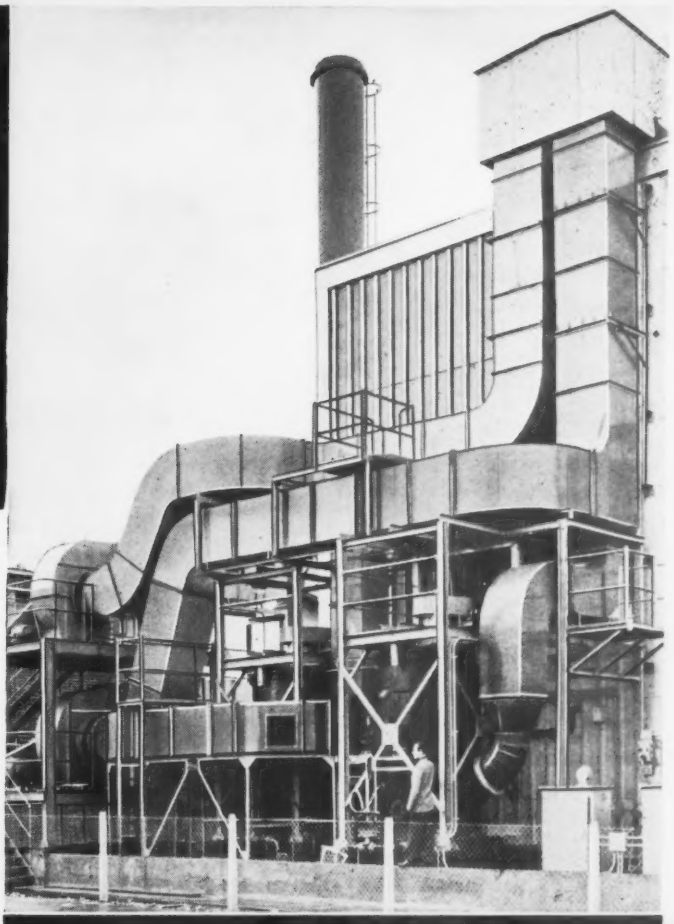

This is a picture of a Kestner Patent Gas Washing Installation, published by permission of the Atomic Energy Authority. Highly corrosive acid fumes are being removed from 11,000 c.f.m. of air. The Gas Washers are constructed in Keebush Grade H (alkali-and-acid-resistant) and the ductwork is of P.V.C.

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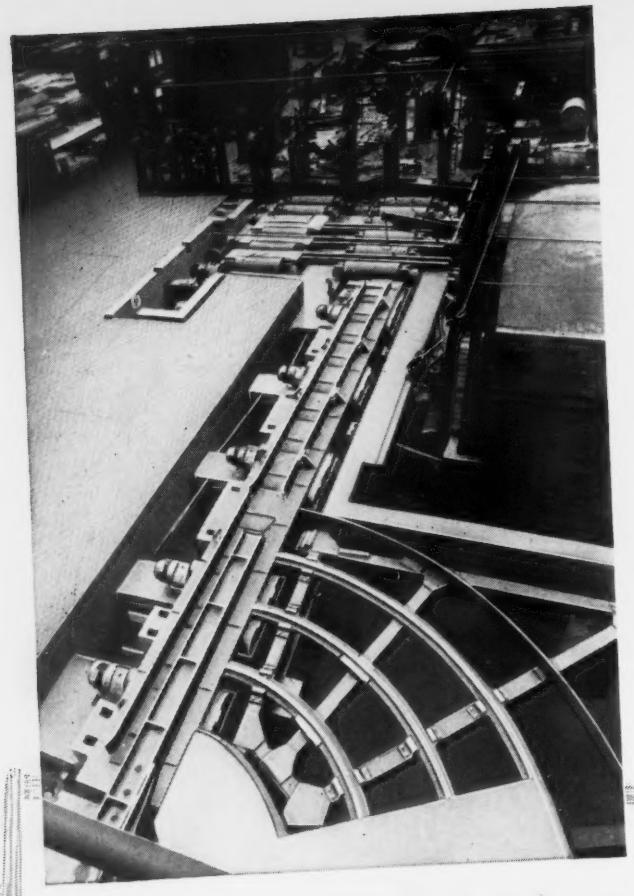

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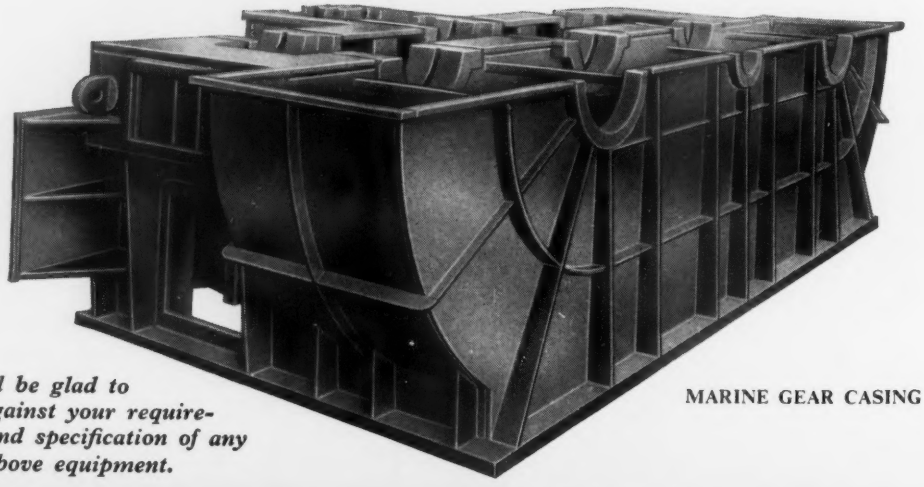

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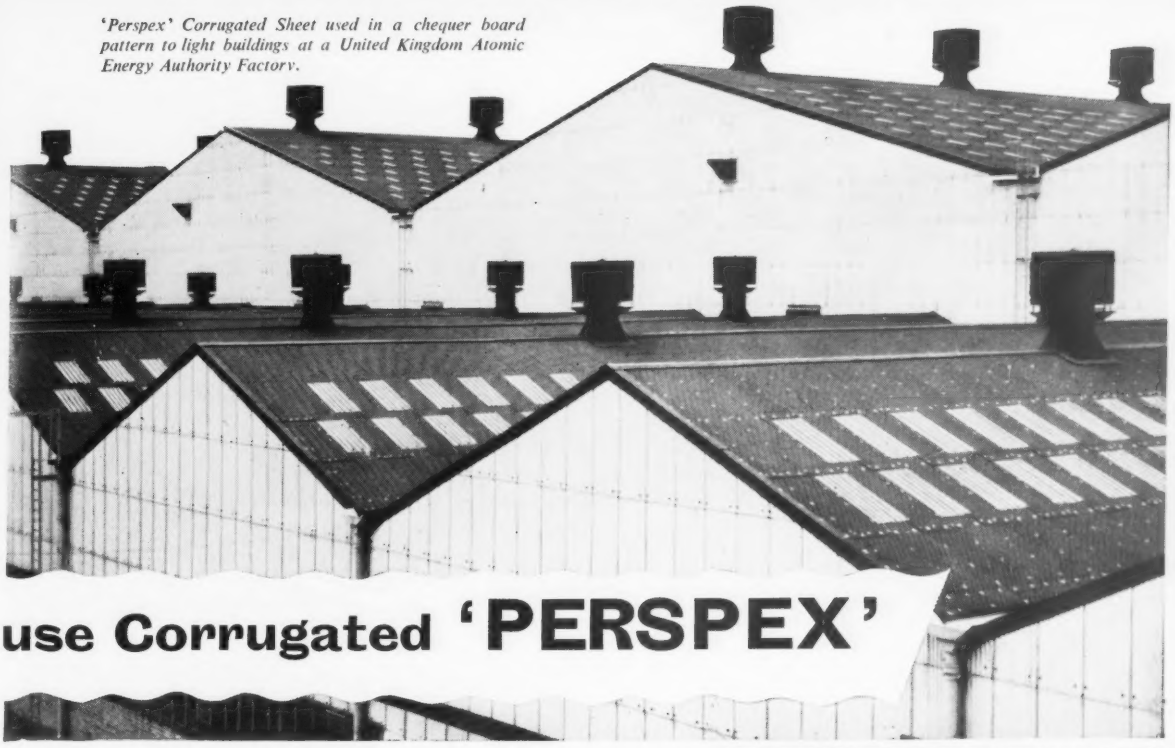

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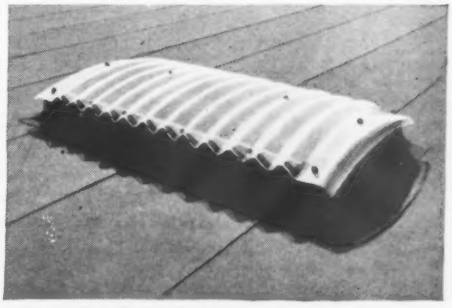
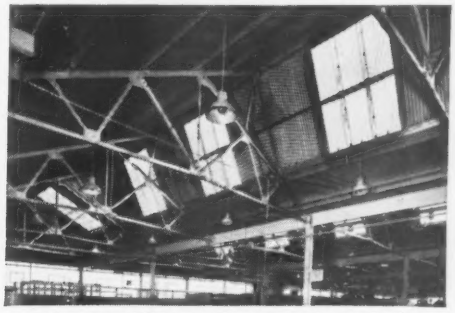


Curved Corrugated 'Perspex' lantern light on a flat roof.



Corrugated 'Perspex' used on the roof of a Royal Ordnance Factory.

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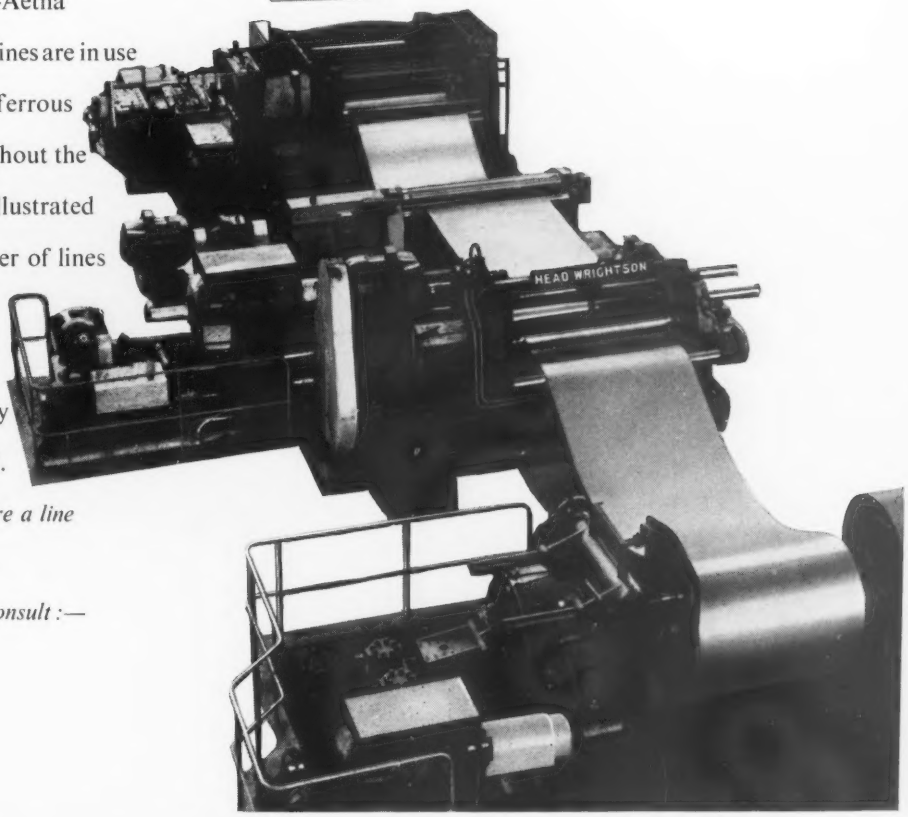

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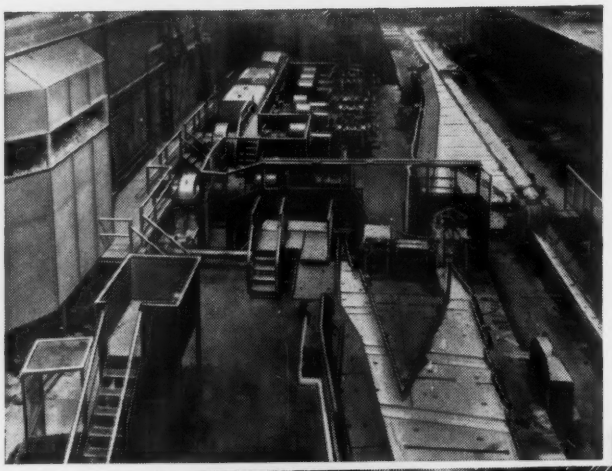

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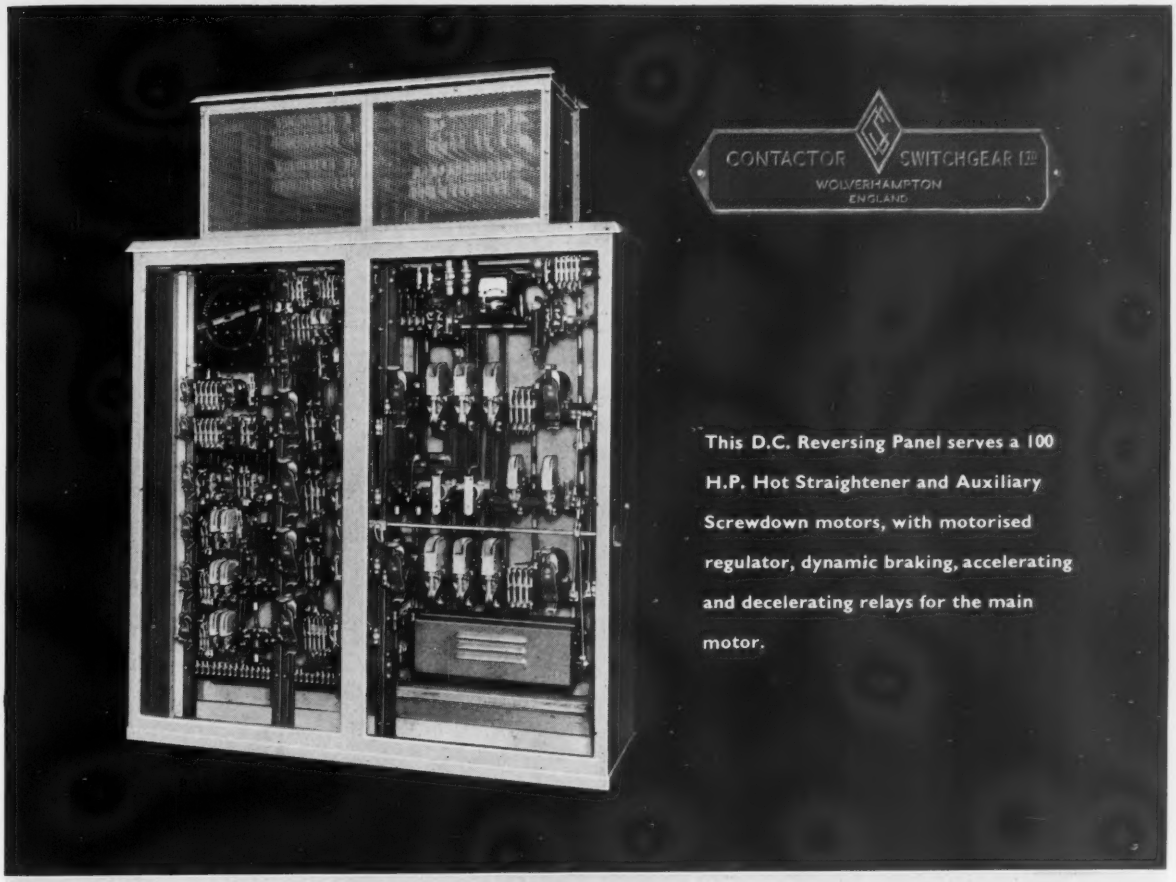

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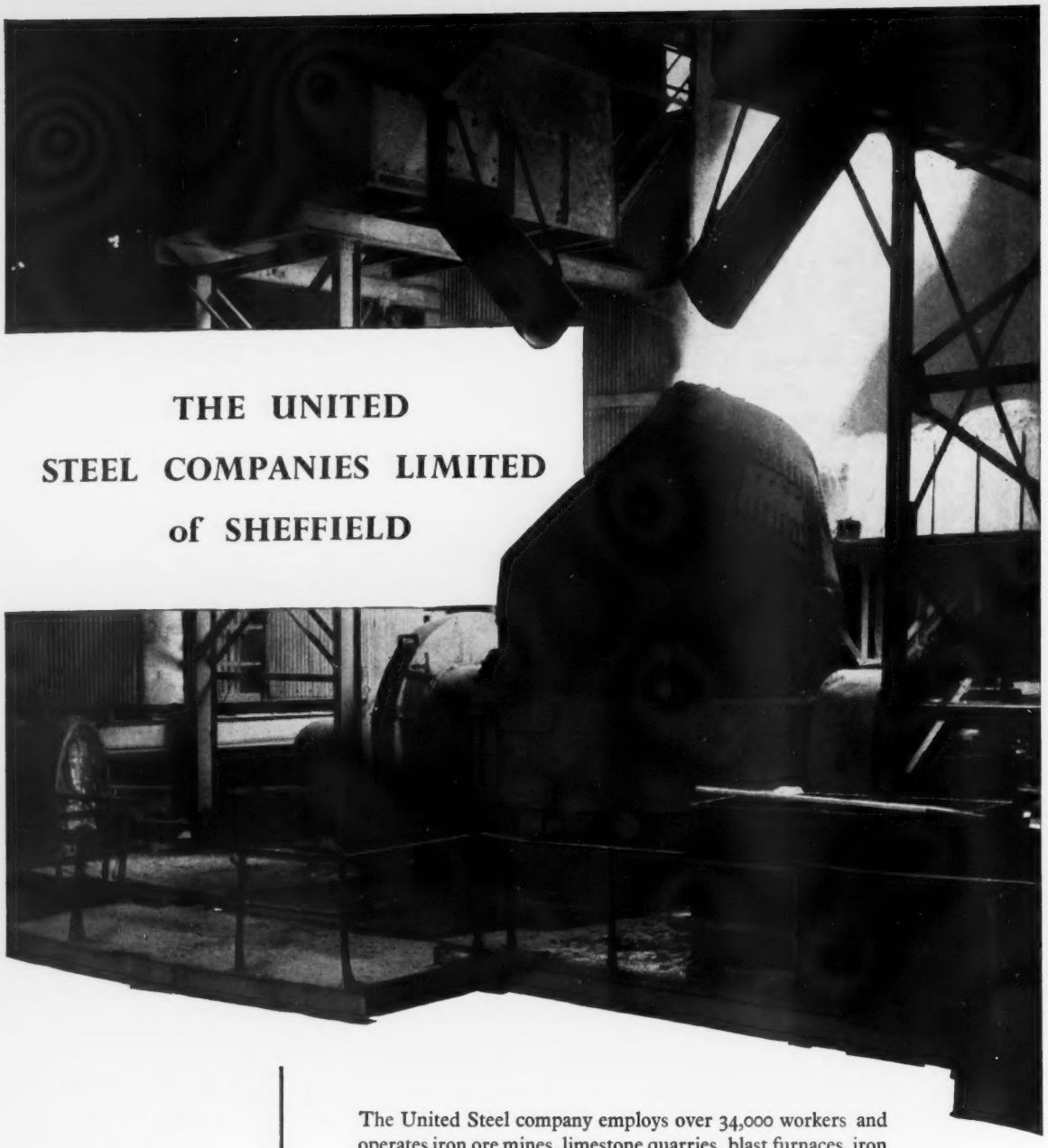

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Journal of The Iron and Steel Institute

AUGUST 1956
Vol. 183 Part 4

Published Monthly
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The Iron and Steel Institute

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ASSISTANT EDITOR
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EDITORIAL AND ADVERTISEMENT OFFICES

4 Grosvenor Gardens, London, S.W.1
SLOane 0061
Telegrams - - Irosamente, Sowest

SUBSCRIPTIONS

Members Free - Extra Copies Prices on application
Non-members - £10.0.0. per annum
Single Copies £1 each
Packing and postage 1s. per copy

NOTE

The Institute as a body is not responsible for statements made or opinions expressed in papers, articles, or discussions appearing in the Journal of The Iron and Steel Institute.

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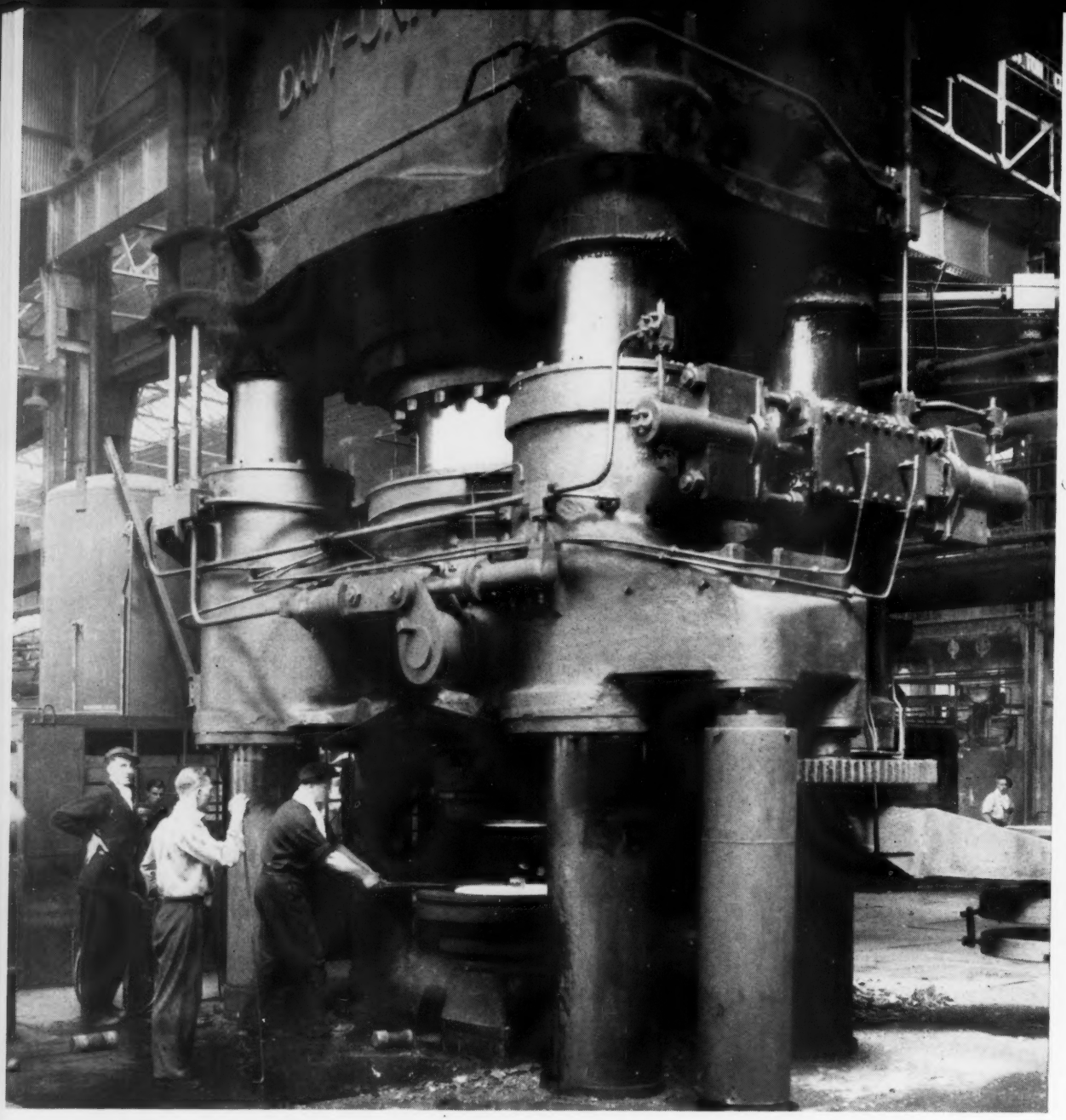
THE IRON AND STEEL INSTITUTE, 4 GROSVENOR GARDENS, LONDON, S.W.1



Wheels for the iron road

From this 6,000 ton Forging Press, installed in a Sheffield steelworks, go solid wheels to the railways of the world. In five operations, taking about 90 seconds, this press forges a wheel blank ready for rolling and finishing from a cheese-shaped ingot weighing some 1,400 lbs. It can produce wheels up to 3′ 7″ diameter, in outputs of the order of 200 per shift. A press of similar type is now being installed in a steelworks in France.

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127 DU

C. BRECKON, B.Sc.

MR. CLIFFORD BRECKON joined The Yorkshire Copper Works Ltd. as an apprentice in the laboratory in August, 1930, shortly before his sixteenth birthday. During his apprenticeship period he studied at evening school, and obtained a B.Sc. Degree with Second Class Honours in Chemistry as an external student of London University in 1936.

In September, 1938, he was made responsible for starting and developing a new section of the works for the manufacture of light-alloy tubes for the aircraft industry. The needs of the aircraft industry for this type of material continued to grow until 1945, when war production started to slow down. At this stage, The Yorkshire Copper Works Ltd. ceased to make light alloy tubing, although Mr. Breckon remained on the production side of the works for a short time before being appointed Deputy Chief Metallurgist in January, 1947.

On behalf of his company Mr. Breckon has visited many foreign countries to investigate problems on the spot and give advice. He has also given talks in various countries on matters concerning the use of non-ferrous tubes, corrosion, etc.

In April, 1954, Mr. Breckon was appointed Chief Metallurgist of the Yorkshire Copper Works Ltd., when his predecessor, Mr. J. Wilkinson, was appointed Technical Manager. In August, 1955, Mr. Wilkinson was compelled, through ill-health, to retire, and Mr. Breckon was appointed to take his place on the Board of Directors, fourteen days before he completed twenty-five years' service with the Company.

Mr. Breckon was President of the Leeds Metallurgical Society for the session 1955/6, and as such served as an Honorary Member of Council of The Iron and Steel Institute.

C. Breckon, B.Sc.

Honorary Member of Council

PROCEEDINGS OF THE INSTITUTE

Reports of Council · Meetings · Notices

Annual General Meeting 1956

The EIGHTY-SEVENTH ANNUAL GENERAL MEETING of THE IRON AND STEEL INSTITUTE was held on Wednesday and Thursday, 16th and 17th May, 1956, the Wednesday morning session at the Royal Institution, Albemarle Street, London, W.1, and the other sessions at the Offices of the Institute, 4 Grosvenor Gardens, London, S.W.1. Sir CHARLES BRUCE-GARDNER, BT., the Retiring President, was in the Chair at the beginning of the Meeting, his place being taken later by Dr. H. H. BURTON, C.B.E., the new President.

Sessions were held at 9.45 A.M. and 2.30 P.M. on the Wednesday and at 9.45 A.M. and 2.15 P.M. on the Thursday. On the Wednesday evening, a Dinner for Members was held at Grosvenor House, Park Lane. This was attended by about 1500 members and guests.

The minutes of the previous meeting were taken as read, and were confirmed and signed.

The **President** (Sir Charles Bruce-Gardner, BT.) expressed the welcome of the Council to Members and visitors, and in particular those from many countries in Europe, and from the U.S.A., as well as from countries of the British Commonwealth.

OBITUARY

The **President,** in speaking of the Members who had died since the previous meeting, mentioned in particular Mr. Harold Boot, a Member since 1941 and a Member of Council since 1951, Mr. Richard Elsdon, for many years Librarian and head of the Information Department, who had been an Honorary Member of the Institute since 1952, and Mr. R. A. Ronnebeck, who was for many years in charge of the service which provides abstracts of technical papers.

The meeting stood in silence for a short time as a token of respect.

PRESENTATION OF REPORT OF COUNCIL AND STATEMENT OF ACCOUNTS FOR 1955

The **President** next presented the Report of Council on the work of the Institute during 1955, and the Accounts, which were published in the May issue of the *Journal*. Membership of the Institute at the end of the year was 5002, the first time that it had exceeded 5000. A Special Meeting was held in Scunthorpe in October and meetings of the Engineers' Group in London, Corby, and Dagenham in September. In connection with the latter, he expressed the Council's gratitude to Mr. W. M. Larke and the members of the Engineering Committee. The Joint Metallurgical Societies Meeting with the American Societies took place in June, and the Council were most appreciative of the high honour accorded by H.R.H. The Duke of Edinburgh when he graciously consented to be Patron.

In connection with this Joint Meeting, three distinguished Americans were elected to Honorary Membership of the Institute: Dr. Howard Biers, Mr. William H. Eisenman (Secretary of the American Society for Metals), and Dr. Ernest O. Kirkendall (Secretary of the American Institute of Mining and Metallurgical Engineers). The great distinction of Honorary Memberships in the American Society for Metals and the American Institute of Mining and Metallurgical Engineers (now called the American Institute of Mining, Metallurgical and Petroleum Engineers) had been conferred on himself and on the Secretary. The President also extended congratulations to the Secretary, Mr. K. Headlam-Morley, on the bestowal of the order of Chevalier de l'Ordre de la Couronne by H.M. The King of the Belgians, as well as on his election as an Honorary Member of the Belgian and German Institutes. (*Applause.*)

The *Journal* and other publications of the Institute had appeared as usual, and it was the constant endeavour of the Council to maintain and improve their quality. The Council were concerned also that the service to members given by the Library and Information Department should be maintained at a high level of efficiency. "We were pleased to get a favourable verdict from the Joint Committee of our Institute and the Institute of Metals which looks after this important branch of our activities," he said, "but we are not complacent, and we are looking into the possibility of the extension and improvement of this service. The same remarks apply to the other things which we try to do for our members. Constant watchfulness is necessary if we are to continue to do what they have a right to require of us."

Relations with other Societies were very friendly. Mutually helpful relations had been maintained with the two big organizations of the British steel industry, the British Iron and Steel Federation and the British Iron and Steel Research Association, as well as with the Iron and Steel Board. Friendship with the Institute of Metals

and the Institution of Metallurgists had been maintained, to their mutual content. The extent of the overlapping in membership was perhaps not always fully realized: 43% of the Members of The Iron and Steel Institute were also members of the Institute of Metals or of the Institution of Metallurgists. The support received from the affiliated Local Societies, of which there were now 12, was greatly valued. The international aspect of the Institute's work—28% of the Members lived overseas—was reflected in the cordial relations maintained with 18 kindred societies in 15 countries.

The **Honorary Treasurer** (Mr. W. Barr), who seconded the motion, then presented the Statement of Accounts. He pointed out that income had risen from £78,133 in 1954 to £79,982. There was a favourable balance of £2738. In view of the present difficulties, the staff of the Institute were to be congratulated on this result and he wished to congratulate in particular the staff of the Editorial Department. The recent dispute in the printing industry had caused a great deal of trouble to those responsible for producing the Institute's publications, and it was only by taking the most vigorous steps that they were able to produce the *Journal*, even though somewhat delayed, in time to save the revenue that accrued from it. It was an interesting point that the revenue from publications was now considerably higher than the revenue from subscriptions.

The surplus of £2700 of the ordinary income and expenditure account had been more than accounted for by the extraordinary non-recurring expenditure. The great bulk of this was due to the money spent on the Offices of the Institute. However, this was money well spent, since the Institute now had a headquarters that was worth visiting. In addition, there was the cost of entertaining foreign visitors, and there was also an account, not yet closed, for the Joint Metallurgical Societies Meeting in Europe, which then stood at £2411.

This extraordinary expenditure had been separated from the other expenditure, in order to make the position clearer in presenting the Accounts. Apart from the fact that the account for the Joint Metallurgical Societies Meeting had not been closed, there was a net deficit of £4904 (excess of expenditure over income) which had been carried to the Accumulated Fund below. A reserve of £3000 had been previously allocated against repairs to the building, and so the net effect was that the Accumulated Fund, which stood at £36,180 on 31st December, 1954, now stood at £30,115, a reduction of approximately £6000. "It is hoped, looking ahead, that we shall be able to build that Fund up again and restore it to the position it occupied at the end of 1954, and even higher if we can manage it."

The usual transfer had been made from the Accumulated Fund to the House Fund, including £1000 to the Cost of Lease Account, which had been written down by £3000 to date.

"The prospects for the next two or three years appear to be satisfactory," Mr. Barr concluded. "We estimate that the income will exceed the expenditure by a small amount. It is important to observe that in spite of increasing costs no increase in the subscription rates payable by members is contemplated at present. We shall do what we can to preserve the *status quo* in that important respect. I do not think that there are many institutions of this sort which have not been in some sort of financial difficulty in these days, and I should like personally to thank the staff for all the work that they have done so efficiently to carry on the work of the Institute."

The motion for the adoption of the Report and Accounts was carried unanimously.

The **President:** I know that you would wish me to thank Mr. Barr for all the work he has done during the year as Honorary Treasurer. (*Applause.*) It is no light duty, as will be seen from the Accounts."

HONORARY MEMBERSHIP

The **President** announced that the Council had elected Sir John Craig, C.B.E., D.L., and Mr. James Spencer Hollings, C.B.E., to be Honorary Members of the Institute in recognition of their distinguished services to The Iron and Steel Institute and to the industry. Sir John Craig had been a Member since 1917; he became a Member of Council in 1922, Vice-President in 1928, and was President in 1940–42. Mr. Hollings had been a Member since 1903; he became a Member of Council in 1930, Vice-President in 1938, an Honorary Vice-President in 1946, and a Bessemer Gold Medallist in 1946. (Mr. Hollings has since died; an obituary notice appears on p. 403.)

THE INSTITUTE OF METALS

The **President** said that The Institute of Metals had shared the office building with The Iron and Steel Institute since 1938. They had now acquired the lease of a house at 17 Belgrave Square and would be leaving 4 Grosvenor Gardens in a few weeks. "We are very sorry that they are leaving us; it has been a happy and, I think, mutually valuable association, but we wish them a very happy tenure of their new home and we are confident that the two Institutes will continue to work as closely together in the future as they have in the past." At the request of the Council of The Institute of Metals, the existing arrangements for the Joint Library at 4 Grosvenor Gardens were to be continued.

It was probable that the Institution of Metallurgists, who left 4 Grosvenor Gardens a year or so ago, would return there in the near future.

BESSEMER CENTENARY

The **President** said, "This year marks the centenary of the first operation of the Bessemer process for steelmaking. This is one of the milestones in the progress of the human race, since then, for the first time, steel was made available in a quantity and at a price which has made possible its extensive use." On the previous evening a brilliant and inspiring lecture had been delivered by Mr. James Mitchell, C.B.E.

An exhibition of pictures, medals, and other things belonging to, or associated with, Sir Henry Bessemer, was being held at the Offices of the Institute. Many of these had been lent by the Bessemer family, to whom he expressed the thanks of the Council. That afternoon papers dealing with the operation of the Bessemer process at Workington were to be discussed, and these papers, Mr. Mitchell's lecture, and other material connected with the centenary were to be published in the June issue of the *Journal*.

PRESENTATIONS TO THE INSTITUTE

The **President** went on to thank those who had made presentations to the Institute. Gifts of money had been received for the use of the Library, including £21 from Imperial Chemical Industries Ltd. and £105 from Gillette Industries Ltd. The Loewy Engineering Company had presented a number of rare books, and many authors had given copies of books which they had written. The Council were also grateful to Miss M. Melville for presenting a fine portrait of her great-grandfather, Josiah Timmis Smith, President in 1881–83. Mr. Fredrik Göransson, Chairman of Sandviken Jernverks A.B., had sent a picture of the first Swedish Bessemer steelworks and photostat copies of many interesting old letters and documents.

Mr. H. Douglas Bessemer and Miss Bessemer, great-grandchildren of Sir Henry Bessemer, had lent valuable heirlooms left by their father, Mr. Henry W. Bessemer, of whose death two months previously at the age of 90 they had learnt with profound regret. They had also presented many items of great interest to the Institute.

PRESENTATION OF MEDALS AND PRIZES

The **Bessemer Gold Medal** for 1956 was presented to Dr. C. Sykes, F.R.S. (Thos. Firth and John Brown Ltd.), a Member of Council, in recognition of his distinguished contribution to the study of alloy systems particularly in the field of order–disorder changes and the effect of such changes on the physical properties of alloys.

The **Sir Robert Hadfield Medal** for 1956 was presented to Mr. H. Morrogh (British Cast Iron Research Association) in recognition of his distinguished contribution to the study of the metallography of cast iron and for researches which resulted in the discovery of nodular iron and the improvement in the quality of cast iron.

A **Williams Prize** for 1954 of £100 was presented jointly to Mr. F. A. Gray and Mr. S. H. Brooks, of the United Steel Companies Ltd., for their paper on "An Investigation of Reheating Furnace Design and Performance," published in the *Journal* for November, 1954.

Two **Williams Prizes** for 1955 of £50 each were presented to Mr. A. J. Kesterton, of the Steel Company of Wales Ltd., for his paper on "Some Starting and Operating Experiences at Abbey Melting Shop," presented before the Cleveland Institution of Engineers and published in the *Journal* for January, 1955, and to Mr. R. Wilcock, of Samuel Fox and Co., Ltd., for his paper on "The Operation of a 60-ton Arc Furnace at Samuel Fox and Co., Ltd.," published in the *Journal* for June, 1955.

Two **Ablett Prizes** for 1955, of £100 each, were presented to the following:

Mr. W. Ernest, of the United Steel Companies Ltd., for his paper on "Waste Heat Recovery related to the Generation of Electric Power," published in the *Journal* for March, 1955.

Mr. S. R. Phelps, of Guest Keen and Nettlefolds Ltd., for his paper on "Flying Shears for Bars and Billets. Electrical Requirements," published in the *Journal* for November, 1955.

A further **Ablett Prize** for 1955 was awarded, but not presented, owing to the recipient's absence in the U.S.A., to Mr. R. Stewartson, of Guest Keen and Nettlefolds Ltd., for his paper on "Flying Shears for Bars and Billets. Mechanical Design Features," published in the *Journal* for November, 1955.

All the presentations were made by the President.

ANNOUNCEMENTS

The **Secretary** (Mr. K. Headlam-Morley) made the following announcements:

Changes on the Council since the last General Meeting in November, 1955:

Election of Vice-President: At the meeting of the Council held on 15th May, 1956, Sir Charles Goodeve, O.B.E., D.SC., F.R.S., an Honorary Member of Council and Director of the British Iron and Steel Research Association, had been elected a Vice-President.

Honorary Members of Council during their periods of office:

Major C. J. P. Ball, President of The Institute of Metals, to succeed Dr. Maurice Cook.

Mr. H. Allsop, President of the Sheffield Metallurgical Association, to succeed Mr. T. H. Arnold.

Mr. L. K. Everitt, President of the Sheffield Society of Engineers and Metallurgists, to succeed Mr. R. E. S. Fisher.

Mr. S. Thomson, a Member of Council of the Iron and Steel Institute, President of the West of Scotland Iron and Steel Institute, to succeed Mr. A. McKendrick as an Honorary Member of Council.

Retiring Members of Council—In accordance with Bye-law 10, the names of the following Vice-Presidents and Members of Council had been announced at the Autumn Meeting, 1955, as being due to retire at the present Annual Meeting:

Vice-Presidents: Mr. G. Steel, Mr. I. F. L. Elliot, and Mr. N. H. Rollason.

Members of Council: Mr. G. H. Johnson, Mr. D. A. Oliver, Dr. C. Sykes, Mr. C. H. T. Williams, and the late Mr. H. Boot.

No other members having been nominated up to one month previous to the present meeting, the retiring Vice-Presidents and four surviving Members of Council were presented for re-election and declared by the President to be duly re-elected.

Election of Member of Council: At the meeting of the Council held on 21st March, 1956, Professor Arthur George Quarrell, D.SC. (Professor of Metallurgy at Sheffield University) had been elected a Member of Council.

Future Meetings: In 1956, the *Special Meeting in France* would be held from 5th to 15th June. The *Autumn General Meeting* would be held in London on 21st and 22nd November.

In 1957, the *Annual General Meeting* would be held in London on 22nd and 23rd May, with a Dinner for Members on 22nd May. In 1957, a *Special Meeting* would be held *in Sheffield* during the week commencing Monday, 8th July.

In 1958, a *Special Meeting in Belgium and Luxemburg* would be held from 17th to 28th June.

Andrew Carnegie Scholarships: The following awards had been made since the last General Meeting:

£400 (second grant) to Mr. P. R. Vaughan Evans (University College, Swansea) to assist research on the mechanical properties and internal stresses of various strip steels after various isothermal treatments.

£250 to Mr. M. Prasad (Liverpool University) to assist research on the peeling of whiteheart malleable cast iron.

Messages of Greeting: The following messages of greeting had been received:

From the Secretary of the American Iron and Steel Institute, Mr. George Rose:

"*Best wishes to your members and your Council on the occasion of your Annual General Meeting and the celebration of the Bessemer Centenary. May the next 100 years be as good.*"

From the Acting Honorary Federal Secretary of the Australian Institute of Metals:

"*I have much pleasure in extending best wishes from my Council for a very successful meeting.*"

From Jernkontoret, Sweden:

"*At Bessemer Century celebration Jernkontoret join in homage to brilliant inventor and in commemoration of decisive departure in steelmaking practice.*"

From Mr. Fredrik Göransson, of Sweden:

"*With deepest regret that I cannot today partake in your meeting. I send you my heartiest greetings and best wishes that the Institute also in coming years and centuries shall prosper and be the strong pillar as it always has been for supporting the world's steel, science and industry.*"

BALLOT FOR THE ELECTION OF MEMBERS

The scrutineers of the ballot, Dr. **L. Northcott** and Mr. **T. Henry Turner,** reported that the following candidates had been duly elected:

Members

Agrell, Hilding (Hallstahammar, Sweden); **Archibald,** A. A. (Pittsburgh, Pa., U.S.A.); **Arlidge,** Cynthia June, B.SC., F.C.S. (London); **Baare,** Paul Adolf, DIPL.ING. (Duisburg-Grossenbaum, Germany); **Baile,** Robert Lewis James, M.I.PLANT.E., M.INST.B.E. (Karachi, W. Pakistan); **Ballass,** John Thomas, M.S., PH.D. (Groton, Conn., U.S.A.); **Bartlett,** William Harry, M.I.STRUCT.E. (Port Talbot); **Bates,** Harold, B.SC. (Middlesbrough); **Beckett,** Maurice (Rotherham); **Belcher,** Peter Richard, B.SC.(HONS.) (Leicester); **Bicket,** Anthony Neilson, M.C. (Holywell); **Biggs,** B. L. (Sheffield); **Binney,** Sir George, D.S.O., B.A. (London); **Bitsianes,** Gust, PH.D., CH.ENG. (Minneapolis, Minn., U.S.A.); **Black,** James C. W. (Middlesbrough); **Bogan,** Laurence Charles, B.SC. (London); **Boudin,** Roger (Paris); **Bowman,** George, A.I.M. (Mossend); **Brown,** Kenneth E. (London); **Bucher,** John Bennett, DIPL.ING. (Sheffield); **Buckley,** Geoffrey Ratcliffe (Nottingham); **Buelga,** Nicolas (Northampton); **Burdett,** Leonard Arthur (Swansea); **Burgham,** E. O. (Weirton, West Virginia, U.S.A.); **Butler,** Arthur Keith (London); **Castle,** Frederick William George (Rotherham); **Chevis,** Annie Henrietta, B.SC. (London); **Childs,** Leonard, M.INST.F. (Dagenham); **Chrétien,** Gabriel (Luxemburg); **Cockburn,** Denison (Wednesbury); **Cockett,** Neil Maxwell, A.I.MAR.E., G.I.MECH.E. (London); **Collcutt,** Roger Hugh, B.SC.(ENG.) (London); **Crowe,** Henry Marloni, B.A. (London); **Dale,** Anthony James, M.A., B.LITT. (London); **Danielsen,** Robert William Nicholas (Birmingham); **Enzian,** George H., B.S., MET.ENGR. (Pittsburgh, Pa., U.S.A.); **Eudier,** Michel, DR.-ING. (Beauchamp, France); **Evans,** Sir Lincoln, C.B.E. (London); **Farren,** Gerard (Haulbowline, Eire); **Fogarty,** John Edward, B.S. (Massillon, Ohio, U.S.A.); **Futcher,** Francis James, ASSOC.MET., A.I.M. (Sheffield); **Garber,** Sidney, B.ENG. (MET.), PH.D. (Sheffield); **George,** Edward Ambrose, B.A. (Stafford); **Ginzberg,** Max, DIPL.ENG. (London); **Gouzou,** Jacques (Charleroi, Belgium); **Grazebrook,** C. J. (Dudley); **Griffiths,** Howard Gladwin, A.M.I.C.E. (Port Talbot); **Hales,** J. M., M.B.E., B.SC. (London); **Hill,** George (London); **Hindson,** William Stanley, B.SC.(ENG.), A.M.I.MECH.E., A.I.M. (London); **Hodge,** Abram L., B.S.(CHEM.ENG.) (Newark, N.J., U.S.A.); **Horchover,** Daniel Macaulay (London); **Hoyt,** Samuel L., SC.D., PH.D., E.M. (Columbus, Ohio, U.S.A.); **Irving,** James, A.M.I.MECH.E., M.I.P.E. (Saltburn-by-Sea); **Jaffrey,** William Graham, B.SC. (London); **Jenkins,** Norman (London); **Jolly,** Reginald (Smethwick); **Joslin,** George Herbert (Upminster); **Jourde,** Pierre (Caen, France); **Keeler,** C. L., M.C. (West Bromwich); **Kemmis,** Owen Henry, B.A. (London); **Kilpatrick,** Thomas Sheldon, M.A. (Workington); **Kopczynski,** Zbigniew Stanislaw, DIPL.ING., M.ENG.SC. (Lucerne, Switzerland); **Lace,** O. C., M.ENG., A.M.I.MECH.E. (Wigan); **Lafforgue,** Roberto N. (La Plata, Argentina); **Layton,** Michael John, B.A., A.M.I.MECH.E. (London); **Leone,** David Paul, B.S. (CHEM. ENG.) (Monessen, Pa., U.S.A.); **Leu,** Kurt Werner, DR.PHIL., PH.D., D.I.C. (Amsterdam, Holland); **Lindquist,** Raymond C., A.B., LL.B., M.S. (Cleveland, Ohio, U.S.A.); **Lowry,** Henry (Rotherham); **Lubanska,** Mrs. Hope (London); **Lytle,** Arthur Roemer, CH.E. (New York, N.Y., U.S.A.); **MacKenzie,** David, A.I.M. (Gwelo, S. Rhodesia); **Makepeace,** C. E., B.ENG.(MET.) (Welland, Ontario, Canada); **Marsh,** John S., B.SC. (Bethlehem, Pa., U.S.A.); **Martin,** Helmut (Werdohl, Westfalen, Germany); **May,** Guy Norman, M.A. (London); **Mazet,** Louis (Ivry-sur-Seine, France); **Moore, Frank** (Sheffield); **Morrogh,** Henton (Birmingham); **Muntaner Coll,** Dr. Jorge S. (Buenos Aires, Argentina); **Myers,** Henry (Rotherham); **Nino Mallón,** Leandro (Madrid, Spain); **O'Connor,** D. (Doncaster); **Pelton,** Bruce Sydney, B.SC.(ENG.), A.M.I.E.E. (Erith); **Posnett,** William Adam (Glasgow); **Prest,** Edward Charles, D.F.C. (London); **Price,** Sir Rose, BT., B.A. (London); **Prosser,** Harry (Warrington); **Pullen,** Rowland H. (Port Talbot); **Rassenfoss,** John A., M.S. (MET. ENG.) (East Chicago, Ind., U.S.A.); **Reeves,** Gordon Leonard, L.I.M. (Birmingham); **Rice,** Alfred E. (London); **Roberts,** Ronald George (Rotherham); **Robinson,** Samuel (London); **Rowen,** Harold E. (Cleveland, Ohio, U.S.A.); **Sandvold,** Knut (Oslo, Norway); **Selmer-Olsen,** Sigurd (Sauda, Norway); **Servi,** Italo Salomone, S.M., SC.D. (Niagara Falls, N.Y., U.S.A.); **Sigalla,** Armand, B.SC., A.C.G.I. (London); **Siriwardene,** Parana Palliya Guruge Lionel, B.SC., PH.D., A.R.I.C., A.I.M. (Colombo, Ceylon); **Slater,** Derek, B.SC. (Crawley); **Somers,** Col. Thomas Vivian, O.B.E. (Halesowen); **Sommer,** Alvin H. (Peoria, Ill., U.S.A.); **Somogyi,** Francis Paul, DIPL.ING., DR.TECHN.SC. (London); **Spreux,** Maxime (Bogota, Colombia); **Sutton,** Arthur Frederick, G.I.MECH.E. (Middlesbrough); **Talim,** Vasant Trimbak, B.SC. (London); **Tesch,** Emmanuel, DIPL.ING. (Luxemburg); **Thomas,** Gerald, B.SC. (Birmingham); **Tovey,** Reginald Percy (Port Talbot); **Traherne,** Cennydd George, M.A., T.D. (Cardiff); **Trotman,** Geoffrey Edward, A.I.M. (Oldbury); **Turton,** Jack, A.MET. (Barnsley); **Von Lindern,** Jan Hendrik (Alblasserdam, Holland); **Walker,** Thomas, A.M.I.MECH.E. (Sheffield); **Webb,** Thomas Basil, B.SC.(ENG.), M.I.MECH.E., MEM.A.S.M.E. (London); **Wilson,** David Birnie, B.SC.(ENG.) (Port Talbot); **Wingate,** George Nigel Fancourt (Sheffield); **Woods,** Victor (Birmingham); **Wright,** Peter Amyas, M.A. (North Ferriby).

Associate Members

Archer, A. J. (Nottingham); **Ashton,** Malcolm Arthur James (Wolverhampton); **Balasundaram,** Lalgudy Jagadesa, B.SC. (Sheffield); **Bancroft,** Philip Rees (Whitchurch); **Barton,** Peter James (Cambridge); **Bateman,** Charles William (Bromsgrove); **Birks,** Neil (Sheffield); **Blincow,** Howard (Sheffield); **Brown,** Clive (Newcastle-upon-Tyne); **Brownlee,** Alan (Middlesbrough); **Chaudhuri,** Sibdas (Rolla, Miss., U.S.A.); **Clarkson,** Harold Richard (Newcastle-upon-Tyne); **Coakham,** John William (Swansea); **Copeman,** Richard C. (Cambridge); **Crawley,** Warwick Lloyd (Cambridge); **Dennis,** John Keith (Nottingham); **Ellis,** Trevor (Liverpool); **Ensor,** Thomas Francis (Birmingham); **Graham,** Stuart Walter (Middlesbrough); **Gray,** Peter Michael (Liverpool); **Hall,** John Brian (Stockton-on-Tees); **Hills,** Arthur William David (Cambridge); **Hobbs,** Dennis (Swansea); **Hukin,** Royden Langton (Liverpool); **Humphreys,** James Graham (Liverpool); **Jindal,** H. D. (Birmingham); **Jones,** Keith Wynne (Liverpool); **Kaplish,** Bal Krishan, B.TECH.(HONS.) (Sheffield); **Kingsley-Jones,** Peter (Swansea); **Loy,** Brian (Sheffield); **Marlow,** Anthony Brian (Croydon); **Marshall,** Brian (Nottingham); **Mellors,** Brian Michael, A.MET. (Sheffield); **Mirza,** Afaq Beg (Wah Cantt, West Pakistan); **Morrell,** Eric Arthur (Liverpool); **Morris,** Kenneth William (Bilston); **Nicholls,** Garth Farnol (Wolverhampton); **Nicholson,** Stanley (Newcastle-upon-Tyne); **Pai,** Narasimha Manjunath (Warrington); **Palentine,** John Edwin (Sheffield); **Richert,** Inge (Miss) (London); **Safdar Ali,** Mohammed, B.S.C.(MECH.ENG.) (Sheffield); **Sandhir,** Rajinder Kumar (Banaras, U.P., India); **Short,** Douglas Alan (Swansea); **Slingsby,** Alan, B.MET. (Weston-super-Mare); **Veevers,** Kenneth (Nottingham); **Walker,** Joseph Arthur (Hayes, Middlesex); **Westlake,** John (Liverpool); **Whiteley,** Kenneth (Leeds); **Wilson,** Robert Neil, B.MET. (Sheffield).

The **President** declared the candidates to be duly elected. They numbered 171, making the total membership of the Institute 4982.

INDUCTION OF THE NEW PRESIDENT

Sir **Charles Bruce-Gardner,** BT., the Retiring President, before vacating the Chair, inducted the new President, Dr. H. H. Burton, C.B.E., into the Chair.

VOTE OF THANKS TO THE RETIRING PRESIDENT

The **President** (Dr. H. H. Burton) then proposed a vote of thanks to the Retiring President, which was seconded by Mr. **W. Barr** (Honorary Treasurer) and carried unanimously.

PRESIDENTIAL ADDRESS

The President then delivered his Presidential Address, " Problems and Progress in Manufacture and Metallurgy " (published in the June, 1956, issue of the *Journal*).

A vote of thanks to the President for his address was proposed by Mr. **James Mitchell,** C.B.E. (Past-President) and seconded by the Honourable **R. G. Lyttelton** (Past-President).

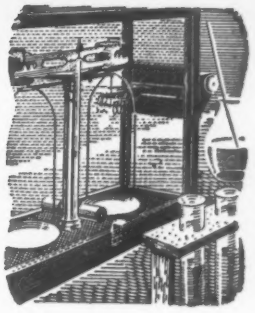
NINTH HATFIELD MEMORIAL LECTURE

The Ninth Hatfield Memorial Lecture was given by Professor **N. F. Mott,** F.R.S., at the Royal Institution, Albemarle Street, London, W.1, on Wednesday, 16th May, 1956, at 11.45 A.M. The President of the Institute, Dr. **H. H. Burton,** C.B.E., was in the Chair. The subject

(*Continued on p.* 403)

PAPERS AND REPORTS ON RESEARCH AND PRACTICE

Metallurgy · Plant Operation · Research



The Temperature of Formation of Martensite and Bainite in Low-alloy Steels

SOME EFFECTS OF CHEMICAL COMPOSITION

By W. Steven, Ph.D., F.I.M., and A. G. Haynes, B.Sc.

SYNOPSIS

Consideration is given to possible sources of error in the Greninger and Troiano method for the determination of martensite formation ranges. The method is used to determine the M_s temperatures of a wide variety of steels and the complete martensite formation ranges of a selection of these steels. These data are used to develop empirical equations relating chemical composition and martensite formation temperatures.

The bainite isothermal transformation characteristics of the same set of steels are determined and empirical equations are developed relating certain features of these with chemical composition. 1138

Introduction

THE MAIN OBJECTIVE of the work described in this paper was to determine the influence of chemical composition on the temperature range within which low-alloy steels transform to martensite. However, as the work progressed, some attention was paid to the influence of chemical composition on certain transformation characteristics of this type of steel in the bainite range. The results obtained from the study of martensite formation ranges are presented in Part I and those obtained from the study of bainite formation are presented in Part II.

Part I—INFLUENCE OF CHEMICAL COMPOSITION ON PROGRESS OF MARTENSITE REACTION

Previous Work

A review of the literature on the influence of chemical composition on the martensite reaction inevitably revolves about the various attempts which have been made to develop empirical equations relating chemical composition and M_s temperatures. The first of these equations, proposed by Payson and Savage,[1] was of the following form:

$$M_s\ (^\circ F) = 930 - 570C - 60Mn - 50Cr - 30Ni - 20Si - 20Mo - 20W.$$

In deriving the first two terms of this formula, Payson and Savage used the results of some of Greninger's[2] work on the effect of carbon content on M_s temperature. They derived the factors for silicon and the alloying elements from a study (by the Greninger and Troiano[3] method) of 17 steels specially prepared for the purpose. Unfortunately all these steels contained about 0·5% carbon and, as a result, the effects observed for the various alloying elements are not necessarily representative of their effects in the presence of the smaller percentages of carbon more characteristic of structural steels. Furthermore, the compositions of the steels studied were such that the results obtained might not reflect the average effects of some of the alloying elements over the ranges encountered in structural steels. For example, the factor selected for molybdenum is based on a straight line drawn through the M_s temperatures of steels containing 1%, 3½%, and more than 5% molybdenum. The average effect of molybdenum over the range 0–0·75%, which is the range generally of most interest, may well differ from the average effect observed over the very wide range studied by Payson and Savage.

Carapella's formula,[4] which is reproduced below, is based wholly on Payson and Savage's data, but is of the multiplying type rather than the simple additive type. It is, therefore, subject to the same comments as the equation proposed by Payson and Savage:

$$M_s\ (^\circ F) = 925 \times f_C \times f_{Mn} \times f_{Ni} \cdots$$

Manuscript received 30th March, 1955.

Dr. Steven is Superintendent of the Birmingham Laboratory of the Mond Nickel Co., Ltd., and Mr. Haynes is a member of the staff.

Table I

ANALYSES OF STEELS STUDIED

Reference No.	B.S. En. No.	Chemical Composition, wt-%								
		C	Si	Mn	S	P	Ni	Cr	Mo	V
1	12	0·34	0·20	1·06	0·040	0·037	0·75	0·08	0·02	...
2	12	0·33	0·21	0·62	0·025	0·022	0·89	0·10	0·05	...
3	13	0·19	0·14	1·37	0·012	0·026	0·56	0·20	0·31	...
4	14	0·29	0·26	1·67	0·030	0·033	0·21	0·12	0·04	...
5	15	0·33	0·23	1·54	0·024	0·021	0·18	0·15	0·05	...
6	16	0·33	0·18	1·48	0·028	0·028	0·26	0·16	0·27	...
7	17	0·38	0·25	1·49	0·028	0·036	...	...	0·41	...
8	18	0·39	0·16	0·89	0·025	0·027	0·25	0·88	Nil	...
9	18	0·48	0·25	0·86	0·021	0·023	0·18	0·98	0·04	...
10	19	0·41	0·31	0·64	0·017	0·030	0·18	1·24	0·38	...
11	19	0·41	0·23	0·67	0·016	0·015	0·20	1·01	0·23	...
12	21	0·33	0·23	0·74	0·027	0·031	3·47	0·07	...	...
13	22	0·40	0·26	0·62	0·005	0·007	3·45	0·28	0·10	...
14	23	0·33	0·23	0·57	0·007	0·005	3·26	0·85	0·09	...
15	23	0·32	0·28	0·61	0·031	0·018	3·22	0·63	0·22	0·03
16	24	0·36	0·22	0·52	0·005	0·007	1·52	1·17	0·27	...
17	24	0·38	0·20	0·69	0·010	0·017	1·58	0·95	0·26	...
18	25	0·32	0·27	0·56	0·012	0·018	2·37	0·74	0·51	...
19	25	0·31	0·20	0·62	0·012	0·018	2·63	0·64	0·58	...
20	26	0·38	0·15	0·56	0·005	0·011	2·42	0·74	0·46	...
21	26	0·42	0·31	0·67	0·022	0·029	2·53	0·72	0·48	...
22	28	0·32	0·19	0·51	0·009	0·013	3·02	1·37	0·48	0·18
23	28	0·25	0·15	0·52	0·024	0·010	3·33	1·14	0·65	0·16
24	30*A*	0·35	0·14	0·44	0·008	0·016	4·23	1·43	0·13	...
25	30*B*	0·33	0·17	0·51	0·009	0·013	4·16	1·44	0·31	...
26	30*B*	0·32	0·29	0·47	0·020	0·022	4·13	1·21	0·30	0·01
27	40*B*	0·26	0·21	0·55	0·022	0·010	0·25	3·34	0·54	...
28	45*A*	0·55	1·74	0·87	0·037	0·038	...	...	...	...
29	47	0·51	0·27	0·72	0·020	0·021	0·15	0·94	0·05	0·20
30	100	0·40	0·24	1·38	0·031	0·033	0·74	0·53	0·16	...
31	100	0·40	0·21	1·34	0·027	0·028	1·03	0·53	0·22	...
32	110	0·44	0·23	0·58	0·004	0·029	1·40	1·26	0·11	...
33	110	0·39	0·23	0·62	0·018	0·021	1·44	1·11	0·18	...
34	111	0·35	0·13	0·65	0·032	0·035	1·27	0·55	Nil	...
35	111	0·37	0·28	0·89	0·035	0·025	1·24	0·63	0·05	...
36	160	0·41	0·13	0·48	0·043	0·016	1·75	0·17	0·22	...
37	32*A*	0·14	0·19	0·50	0·043	0·031	0·19	0·16	0·06	...
38	33	0·10	0·25	0·46	0·006	0·007	3·00	0·13	0·12	...
39	34	0·15	0·16	0·40	0·021	0·019	1·78	0·23	0·27	...
40	35	0·24	0·17	0·42	0·005	0·010	1·84	0·18	0·20	...
41	36	0·14	0·19	0·46	0·009	0·006	3·55	1·11	0·12	...
42	36	0·15	0·25	0·41	0·008	0·020	3·02	0·90	0·15	...
43	37	0·09	0·33	0·33	0·031	0·018	4·87	0·13	0·08	...
44	38	0·11	0·21	0·30	0·004	0·014	5·04	0·13	0·30	...
45	39*B*	0·15	0·20	0·38	0·018	0·027	4·33	1·16	0·17	...
46	39*B*	0·14	0·28	0·45	0·017	0·016	4·11	1·11	0·24	...
47	39*B*	0·15	0·23	0·33	0·015	0·015	4·25	1·11	0·25	...
48	320	0·14	0·22	0·50	0·015	0·010	2·13	2·00	0·18	...
49*	325	0·20	0·11	0·53	0·005	0·026	1·75	0·50	0·25	...
50	352	0·20	0·15	0·71	0·018	0·032	1·13	0·80	0·05	...
51	353	0·18	0·26	0·93	0·008	0·016	1·34	1·11	0·11	...
52	354	0·19	0·21	0·90	0·015	0·017	1·87	1·08	0·18	...
53	...	0·40	0·23	0·52	0·004	0·008	1·83	1·25	1·00	0·15
54*	...	0·31	0·13	0·54	0·025	0·011	1·67	1·24	0·24	...
55*	...	0·41	0·35	0·58	0·020	0·013	1·43	1·27	0·31	...
56*	...	0·49	0·17	0·52	0·022	0·013	1·50	1·28	0·29	...
57*	...	0·38	0·33	0·55	0·021	0·010	0·16	1·25	0·31	...
58*	...	0·38	0·12	0·56	0·024	0·017	3·00	1·21	0·29	...
59*	...	0·38	0·12	0·57	0·023	0·010	4·95	1·22	0·29	...
60*	...	0·41	0·15	0·52	0·027	0·016	1·46	2·10	0·29	...
61*	...	0·37	0·12	0·52	0·026	0·012	1·51	2·90	0·29	...
62*	...	0·40	0·30	0·55	0·025	0·011	1·47	1·22	0·52	...
63*	...	0·36	0·16	0·56	0·029	0·009	1·46	1·22	0·31	0·13
64*	...	0·39	0·26	0·20	0·022	0·009	1·66	1·22	0·26	...
65*	...	0·40	0·27	0·84	0·025	0·012	1·75	1·23	0·27	...

* Steels manufactured under laboratory conditions

the factors for the various elements being

$f_C = 1 - 0{\cdot}620$ C; $f_{Si} = 1 - 0{\cdot}033$ Si; $f_{Mn} = 1 - 0{\cdot}092$ Mn; $f_{Cr} = 1 - 0{\cdot}070$ Cr; $f_{Ni} = 1 - 0{\cdot}045$ Ni; $f_{Mo} = 1 - 0{\cdot}029$ Mo; $f_W = 1 - 0{\cdot}018$ W; $f_{Co} = 1 + 0{\cdot}120$ Co.

Rowland and Lyle,[5] as a result of a limited number of tests, suggested that the carbon factor proposed by Payson and Savage should be raised from 570 to 600. Even with this modification, however, they were unable to obtain adequate agreement between their experimental observations and their calculated values.

Lack of agreement between calculated and experimentally determined M_s temperatures prompted Nehrenberg[6] to review all the data on which the Payson and Savage formula was based, and to propose the modified version

$$M_s\,(^\circ F) = 930 - 540C - 60Mn - 40Cr - 30Ni - 20Si - 20Mo.$$

This formula must be regarded as the most satisfactory of those based on the experimental work of Payson and Savage.

Grange and Stewart's formula[7] is based on an analysis of all the data available in 1946, and differs quite significantly from those suggested by previous investigators:

$$M_s\,(^\circ F) = 1000 - 650C - 70Mn - 35Ni - 70Cr - 50Mo.$$

Grange and Stewart were unable to select, from the

information available to them, reliable factors for either Cr or Mo. They also chose '1000—650C' as the first two terms of their equation, whereas Payson and Savage originally selected '930—570C,' and Nehrenberg later chose '930—540C.' All three are based on Greninger's work, but the latter investigated two series of steels and the results obtained permit some latitude in interpretation.

The literature on the influence of chemical composition on the subsequent progress of the martensite reaction, at temperatures below the M_s temperature, is very limited; and it will be more convenient to consider this at the appropriate stages of the discussion of the results obtained in the investigation about to be described.

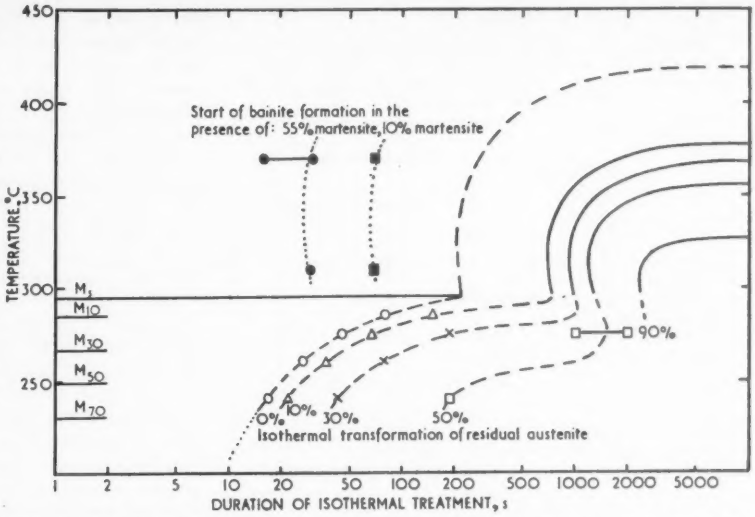


Fig. 1—Bainite and martensite formation characteristics of a B.S. En. 30*B* steel (steel 26)

EXPERIMENTAL PROCEDURE

The analyses of the various steels used are listed in Table I. Most were of normal commercial manufacture, but a few were made in a small H.F. furnace under laboratory conditions.

Martensite formation temperature ranges were studied using the microscopic method described by Greninger and Troiano.[3] This method involves quenching small samples of the steel from the austenitizing temperature to a series of temperatures within and near the martensite formation range. These are tempered immediately, for a time, and at a temperature which will darken any martensite formed but will not allow isothermal transformation, and then quenched to room temperature. The proportion of tempered martensite in the microstructure of each sample is assessed, and from the results a curve of percentage transformation *v.* temperature can be constructed.

For most of the steels only M_s temperatures were determined, but for a few of the steels, complete curves of percentage martensite *v.* temperature were derived. In the early stages of the latter phase of the work a number of possible sources of error inherent in the microscopic method became apparent. These were investigated and the results obtained are discussed below before considering the martensite transformation data.

Bainite Formation

The results obtained by the Greninger and Troiano microscopic method can be influenced by bainite forming in the test samples. The likelihood of bainite forming at temperatures above the M_s temperature during the quench to the test temperature can be assessed from the isothermal transformation diagram. The bainite incubation period decreases discontinuously at the M_s temperature, however, and the chances of bainite forming below the M_s temperature are greater than would be anticipated from an extrapolation of the bainite transformation lines from temperatures above the M_s. This is illustrated by Fig. 1 which shows that the bainite incubation period of a B.S. En. 30*B* steel (steel 26) decreases sharply from about 200 s at its M_s temperature to 30 s only 30° C below its M_s temperature, and continues to decrease with further fall of temperature.

The bainite incubation periods at temperatures below the M_s temperature were determined by a modification of the Greninger and Troiano method. The test cycle was similar to that used for the determination of the M_s–M_f range, but a series of specimens was quenched to each of four temperatures in the martensite range and the duration of the period of holding at each of these temperatures was increased until the amount of tempered product visible in the fully heat-treated sample increased. This was assumed to indicate the start of bainite formation.

The presence of martensite also accelerates the formation of bainite at temperatures above the M_s temperature. Consequently the chances of forming bainite during the tempering stage of the test cycle are greater than would be anticipated from the isothermal transformation diagram. This is also illustrated by Fig. 1 which shows that the presence of 10% and 55% martensite reduce bainite incubation periods by factors of times 3 and times 7 respectively.

These modified bainite incubation times, which are shown by dotted lines in Fig. 1, were determined by a further modification of the Greninger and Troiano method. Small specimens were quenched to the appropriate temperature in the martensite formation range to develop the requisite percentage of martensite. These were then held for varying times at temperatures in the bainite range, before tempering and quenching to room temperature in the normal manner. The duration of the period at the second temperature required to effect an increase in the amount of

Table II

INFLUENCE OF ETCHING REAGENT ON APPARENT PROPORTION OF TEMPERED MARTENSITE IN SAMPLES OF A B.S. En 30*B* STEEL (STEEL NO. 26)

Etching Reagent	Apparent Percentage of Tempered Martensite	
	Sample *A*	Sample *B*
2% nitric acid in alcohol	43	76
4% nitric acid in alcohol	42	76
4% picric acid, 1% nitric acid in alcohol	40	74
1% picric acid, 5% hydrochloric acid in alcohol	49	83

tempered transformation product visible in the final structure was assumed to represent the bainite incubation period in the presence of martensite.

The marked effect of martensite on bainite incubation periods does not restrict the suitability of the Greninger and Troiano method for the determination of M_s temperatures. It does, however, interfere with its usefulness as a method of studying martensite formation temperatures below M_s by restricting its application to steels of relatively high alloy content.

Errors Inherent in Assessing the Proportion of Untempered Martensite in a Structure

The success of the microscopic method for the determination of martensite formation ranges depends on the accurate estimation of the proportions of tempered and untempered martensite in the structures of each of a series of samples. Methods such as ' point counting ' and ' lineal analysis ' can be adopted and mechanical devices can be used to assist in recording the results. However, the observer alone must decide, from visual examination, whether a given zone in the structure is ' tempered ' or ' untempered.' In most cases there is little doubt, but many microstructures, particularly those of samples quenched to temperatures below M_{50}, contain some areas which cannot be easily classified. Consequently the results obtained are dependent to some extent on the personal element.

An obvious essential is to establish whether the apparent proportions of tempered and untempered martensite in the structure are independent of the etchant. To confirm this the proportions of tempered martensite in two samples were assessed after etching in several different reagents. The results (*see* Table II) show that substantially the same result was obtained with three different etchants, but a significantly different result was obtained with the 1% picric, 5% hydrochloric reagent. The latter developed less uniform contrast between the areas of tempered and untempered martensite than the other reagents. No results are quoted for picral since this reagent failed to etch the structure appreciably in a reasonable time.

If the estimates are made while viewing the structures directly under a microscope, or projected on to a screen, it is sufficient to ensure a satisfactory etch and adequate magnification and illumination. However, it is often convenient to photograph representative areas and to derive the results from a detailed examination of photomicrographs. This obviously raises the possibility of further errors being introduced by the degree of contrast between the tempered and untempered martensite being modified during the preparation of the photographic negatives and again during the preparation of the positive prints.

To assess the likely magnitude of such errors, the progress of the martensite reaction with temperature in a sample of B.S. En 30*B* steel (steel 26) was determined, first by point-counting using a graticule in the eye-piece of the microscope and then by photographing typical areas and area-counting photographic prints. As Table III shows, the results obtained by the two methods were in close agreement. Other data in the same table demonstrate that the proportion of tempered and untempered martensite in a microstructure can be estimated visually, by an experienced investigator, with adequate accuracy for the purpose of the present investigation. Charts showing known degrees of transformation were prepared to assist these visual estimates and were used throughout the remainder of the investigation.

Confirmation of the Accuracy of the Microscopic Method by Dilatation Tests

In view of the various sources of error inherent in the microscopic method it was hoped to obtain a cross-check by re-determining the martensite formation range of at least one steel by one other method. The dilatometric technique seemed the most suitable and the M_s–M_f range of the B.S. En. 30*B* steel (steel 26) was determined using 0·1-in. dia. test specimens and a push-rod/dial-gauge dilatometer of the type frequently used for the determination of isothermal transformation diagrams.

The test specimen was cooled from the austenitizing temperature at an average rate of 30° C/min (measured between 300° and 0° C) and dilatation/temperature values recorded over the range 500° to — 196° C. From these a curve was derived representing martensite formation with decrease in temperature. The slope of this dilatation/temperature curve between 100° and — 150° C (sample 1, Table IV) was, however, markedly less than that obtained from a fully transformed sample cooling through the same temperature range (sample 12, Table IV). This suggested that austenite transformation continued over this entire temperature range. X-ray tests and magnetic measurements demonstrated the presence of 2–5% residual austenite in the specimen after cooling in the dilato-

Table III

REPRODUCIBILITY OF ASSESSMENT OF PROPORTION OF TEMPERED MARTENSITE IN SAMPLES OF A B.S. En 30*B* STEEL (STEEL NO. 26)

Method of Assessment	Percentage of Martensite at:			
	260° C	240° C	220° C	200° C
Photographic Method				
Area counting	33	57	74	85
Microscopic Examination				
Point counting	33	53	69	83
Visual estimation	35	55	70–75	85–90

Table IV

RESULTS OF DILATATION TESTS ON A B.S. En 30*B* STEEL (STEEL 26)

Sample No.	Method of Cooling from Austenitizing Temperature	Average Coefficient of Thermal Contraction × 10^6				
		100° C to 50° C	50° C to 0° C	0° C to −50° C	−50° C to −100° C	−100° C to −150° C
1	Slow-cooled to −196° C	4·4	4·8	5·2	7·2	8·0
2	Quenched to 240° C and slow-cooled	4·8	5·4	5·8	...	...
3	„ „ 200° C „ „ „	6·4	6·4	6·4	...	...
4	„ „ 180° C „ „ „	4·4	5·0	6·6	...	...
5	„ „ 160° C „ „ „	4·4	6·0	7·2	...	...
6	„ „ 100° C „ „ „	12·4	11·2	...	...	...
7	„ „ 60° C „ „ „	...	11·0	9·2	...	...
8	„ „ 20° C „ „ „	...	...	9·4	8·8	8·2
9	„ „ 0° C „ „ „	...	...	9·6	9·0	8·2
10	„ „ −40° C „ „ „	...	...	...	9·0	8·0
11	„ „ −78° C „ „ „	...	...	...	...	8·0
12	Quenched to −196° C, reheated and slow-cooled (fully transformed)	11·6	11·0	9·6	9·0	8·2

meter to − 196° C and then re-heating to room temperature.

It was suspected that the results obtained by this method were affected by the phenomenon usually referred to as ' stabilization of austenite.' The following experiments were made to obtain confirmatory evidence.

Each of a series of specimens was quenched in turn in a dilatometer to temperatures in the range 240° to − 78° C and then cooled slowly to − 196° C during which dilatation and temperature values were recorded. The results (given in Table IV) show that the rates of contraction during subsequent slow cooling of specimens quenched to temperatures in the range 240° to 160° C (samples 2–5) were similar to those observed in the initial dilatometric test (sample 1). However, samples quenched to temperatures of 100° C or lower before slowly cooling (samples 6–11) had contraction rates similar to that of the fully transformed sample (12) and an X-ray examination of a few of these revealed no retained austenite.

These results suggest that austenite stabilization occurred in the samples owing to the relatively slow cooling rates achieved in the dilatometric tests. It was not possible, therefore, to confirm by this method the accuracy of the microscopic method. The most convincing confirmation of the accuracy of the results obtained is, perhaps, the closeness of the correlations observed between the martensite formation ranges of the various steels studied.

Standard Procedure adopted to Determine Martensite Formation Ranges

The following are the details of the standard procedure adopted to determine the martensite formation ranges and the M_s temperatures in Tables V and VI.

The specimens used were approximately $\frac{3}{4}$ in. × $\frac{1}{4}$ in. × 0·03 in. and were generally cut from tape formed by drawing and cold-rolling $\frac{3}{8}$-in. dia. hot-rolled bar. Each specimen was nickel-plated to minimize decarburization during the test cycle and then austenitized for 30 min in a salt bath at the appropriate temperature (usually the mean of the range recommended in B.S. 970).

To determine the complete temperature range of martensite formation, specimens of the selected steels were quenched for 5 s in liquid baths at temperatures in, or near, the M_s–M_f range. After exposure at the test temperature the specimens were tempered immediately before quenching to room temperature, for 20–120 s at a temperature just above the bainite 'shelf'. The relevant details are given in Table V.

Table V

MARTENSITE FORMATION RANGES OF SELECTED STEELS

Reference No.	B.S. En. No.	Experimental Details			Martensite Formation Temperature, °C				
		Austenitizing Temp., °C	Duration of Quench, s	Tempering Treatment	M_S	M_{10}	M_{50}	M_{90}	M_f
13	22	860	5	20 s at 640° C	280	270	225	165	50
14	23	835	5	20 „ 550° C	300	290	245	185	80
16	24	835	5	20 „ 550° C	325	315	285	225	110
18	25	835	5	20 „ 550° C	335	325	290	235	130
20	26	835	5	20 „ 550° C	305	295	255	200	100
22	28	835	5	20 „ 550° C	315	305	275	225	100
24	30*A*	820	5	20 „ 550° C	290	280	240	175	60
25	30*B*	820	5	20 „ 550° C	295	285	245	185	70
26	30*B*	820	5	120 „ 500° C	295	285	250	190	100
30	100	860	5	20 „ 550° C	300	290	255	195	100
32	110	860	5	20 „ 550° C	300	290	250	190	80

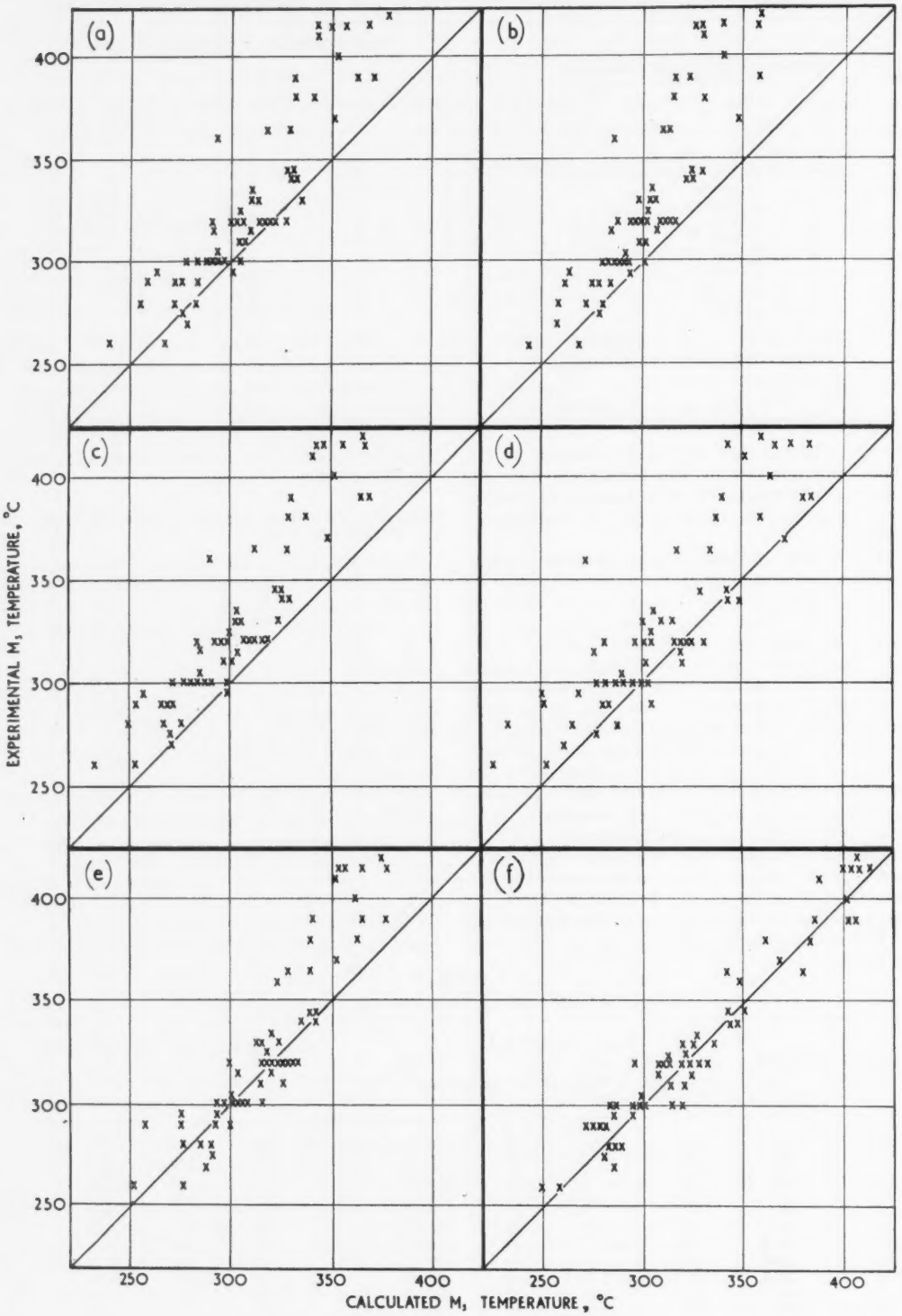

(a)
(b)
(c)
(d)
(e)
(f)
400
350
300
250
EXPERIMENTAL M, TEMPERATURE, °C
CALCULATED M, TEMPERATURE, °C

Table VI

M_s TEMPERATURES AND SOME BAINITE FORMATION CHARACTERISTICS OF THE STEELS STUDIED

Reference No.	B.S. En No.	Austenitizing Temp., °C	Martensite Formation		Bainite Formation		
			Tempering Treatment	M_s Temp., °C	B_s Temp., °C	B_{50} Temp., °C	B_f Temp., °C
1	12	845	5 s at 690° C	345	...	...	...
2	12	845	5 „ 700° C	370	...	...	...
3	13	870	10 „ „	420	600	520	460
4	14	860	5 „ „	380	(560)	500	450
5	15	860	10 „ „	340	...	...	...
6	16	845	10 „ „	340	580	520	460
7	17	845	10 „ „	320	550	500	440
8	18	860	10 „ 350° C	320	560	500	460
9	18	„	10 „ 700° C	300	560	500	440
10	19	„	600 „ 550° C	320	540	480	420
11	19	„	10 „ 700° C	330	570	510	450
12	21	840	10 „ 620° C	310	(570)	(530)	(460)
13	22	860	20 „ 640° C	280	540	480	410
14	23	835	20 „ 550° C	300	500	450	390
15	23	„	20 „ „	320	520	460	390
16	24	„	20 „ „	325	530	470	420
17	24	„	20 „ „	320	530	470	410
18	25	„	20 „ „	335	510	450	390
19	25	„	20 „ „	330	500	440	380
20	26	„	20 „ „	305	520	460	400
21	26	„	20 „ „	290	480	420	360
22	28	„	20 „ „	315	440	390	340
23	28	„	20 „ „	330	470	410	350
24	30*A*	820	20 „ „	290	420	360	310
25	30*B*	„	20 „ „	295	420	350	...
26	30*B*	„	120 „ 500° C	295	420	360	...
27	40*B*	900	20 „ 550° C	360	450	400	...
28	45*A*	915	10 „ 340° C	290	...	...	...
29	47	875	10 „ 380° C	290	560	510	450
30	100	860	20 „ 550° C	300	530	480	420
31	100	845	20 „ „	300	520	460	400
32	110	860	20 „ „	300	520	460	420
33	110	845	20 „ „	320	520	460	410
34	111	„	5 „ 690° C	345	...	...	(490)
35	111	„	3 „ 360° C	315	(600)	490	440
36	160	„	5 „ 690° C	320	...	(540)	(490)
37	32*A*	885	...	...	...	...	(600)
38	33	865	...	...	...	...	(500)
39	34	„	...	...	...	(600)	(520)
40	35	„	...	...	640	560	500
41	36	„	500 „ 700° C	415	550	480	...
42	36	„	10 „ 700° C	415	580	520	...
43	37	„	...	...	...	...	(460)
44	38	„	600 „ 600° C	390	550	500	430
45	39*B*	„	900 „ 540° C	365	500	430	...
46	39*B*	„	20 „ 540° C	390	500	450	...
47	39*B*	„	100 „ 700° C	380	500	430	...
48	320	„	600 „ 560° C	415	520	450	...
49	325	„	10 „ 700° C	390	(620)	560	490
50	352	„	10 „ 730° C	415	(600)	540	480
51	353	„	10 „ 730° C	400	(560)	500	430
52	354	„	10 „ 730° C	410	530	470	420
53	...	860	300 „ 590° C	275	450	380	320
54	...	880	600 „ 500° C	365	530	470	420
55	...	„	600 „ 500° C	300	490	430	370
56	...	„	15 „ 450° C	260	480	420	370
57	...	„	30 „ 600° C	320	550	490	430
58	...	„	15 „ 450° C	280	450	400	340
59	...	„	15 „ 450° C	260	370	330	...
60	...	„	...	...	430	370	330
61	...	„	8 „ 500° C	280	400	360	300
62	...	„	600 „ „	320	(450)	410	380
63	...	„	8 „ „	300	500	450	400
64	...	„	8 „ „	310	540	470	420
65	...	„	8 „ „	270	450	400	340

Only M_s temperatures were determined for most of the steels and it was sufficient, therefore, to ensure for these steels that the duration of the quench at, or near, the M_s temperature, and the time at the tempering temperature did not exceed the appropriate incubation periods indicated by the relevant isothermal transformation diagram. The tempering treatments used in these experiments are listed in Table VI.

It was necessary to temper some of the steels of low hardenability at temperatures in the upper region of the pearlite transformation range.

The heat-treated samples were sectioned and etched in 2% nital. The percentage of tempered martensite in each specimen was then estimated by visual microscopic examination and from these values the M_s temperatures and martensite formation ranges were obtained.

(*a*) Calculated using the Payson and Savage formula[1]:
M_s (° F) = 930 − 570C − 60Mn − 50Cr − 30Ni − 20Si − 20Mo − 20W

(*b*) Calculated using the Carapella formula[4]:
M_s (° F) = 925 × (1 − 0·620C)(1 − 0·092Mn)(1 − 0·033Si) (1 − 0·045Ni) (1 − 0·070Cr)(1 − 0·029Mo)(1 − 0·018W)(1 + 0·120Co)

(*c*) Calculated using the Rowland and Lyle formula[6]:
M_s (° F) = 930 − 600C − 60Mn − 50Cr − 30Ni − 20Si − 20Mo − 20W

(*d*) Calculated using the Grange and Stewart formula[7]:
M_s (° F) = 1000 − 650C − 70Mn − 70Cr − 35Ni − 50Mo

(*e*) Calculated using the Nehrenberg formula[8]:
M_s (° F) = 930 − 540C − 60Mn − 40Cr − 30Ni − 20Si − 20Mo

(*f*) Calculated using the authors' formula:
M_s (° C) = 561 − 474C − 33Mn − 17Cr − 17Ni − 21Mo
M_s (° F) = 1042 − 853C − 60Mn − 30Cr − 30Ni − 38Mo

Fig. 2—Comparison of calculated and experimentally determined M_s temperatures

Table VII

STANDARD DEVIATION VALUES OF THE TERMS OF THE M_s AND B_s FORMULÆ

Formula	Degrees of Freedom to Compute Formula	Standard Deviation Values of Terms					
		Constant	C	Mn	Ni	Cr	Mo
M_s formula	52	15	21	9	2	3	10
B_s formula	43	19	23	9	2	4	11

RESULTS

M_s Temperatures

The agreement observed between the experimentally determined M_s temperatures and those calculated using five of the formulæ proposed in the literature is illustrated by Figs. 2*a–e*. The formulæ proposed by Payson and Savage,[1] Carapella,[4] Rowland and Lyle,[5] and Grange and Stewart,[7] gave calculated values which, on average, were lower than the experimentally observed values (Figs. 2*a–d*). The discrepancy between the two values, in general, increased with decrease of carbon content, being as much as 80° C for some of the carburizing steels.

The M_s temperatures calculated for steels of medium carbon content, from Nehrenberg's[6] formula, were within ± 20° C of the experimentally observed values, but the values for steels containing less than about 0·25% carbon were up to 60° C low (Fig. 2*e*).

A statistical analysis of the results, using the method of least squares, provided the following relationship between chemical composition and M_s temperature.

$$M_s\,(°C) = 561 - 474\,C - 33\,Mn - 17\,Ni - 17\,Cr - 21\,Mo \ldots (1)$$

The formula proposed allows the M_s temperature of a steel within the following limits of chemical composition to be calculated with 90% confidence to within ± 20° C of the experimental value (Fig. 2*f*). However, it must be emphasized that the formula assumes that complete solution of carbide is effected during the austenitizing treatment:

Carbon	0·1–0·55%	Nickel	Trace–5·0%
Silicon*	0·1–0·35%	Chromium	Trace–3·5%
Manganese	0·2–1·7%	Molybdenum	Trace–1·0%

This range includes most of the B.S. En constructional steels but covers few tool steels or carburized cases. These two latter types of steel, however, are not usually austenitized at temperatures allowing full solution of carbide and it is therefore unlikely that a simple formula of the kind under consideration would be applicable.

Only the first two terms of the proposed equation differ significantly from those of the formula suggested by Nehrenberg, if due account is taken of the standard deviation values for each factor (Table VII). The first two terms proposed are considered more reliable than those hitherto suggested, since the work on which they are based represents, as far as the authors are aware, the first study by the microscopic method of steels covering adequately the range of carbon contents usually encountered in structural steels and in the cores of carburizing steels. Greninger's data, on which the first two terms of most of the alternative formulæ are based, were derived by the less sensitive method of analysing time/temperature curves determined from samples cooling rapidly from the austenitizing temperature.

Varying the silicon content over the limited range covered by the tests did not have a significant effect and therefore no factor for this element has been included in the equation.

Rate of Formation of Martensite with Decrease of Temperature

Although martensite formation started at a different temperature in each of the eleven steels studied in this investigation (Table V), the interval between M_s and M_f was practically the same for all the steels and all formed martensite at substantially the same rate with fall of temperature. The formation of the first 70%

* Steel 28 contained 1·74% silicon.

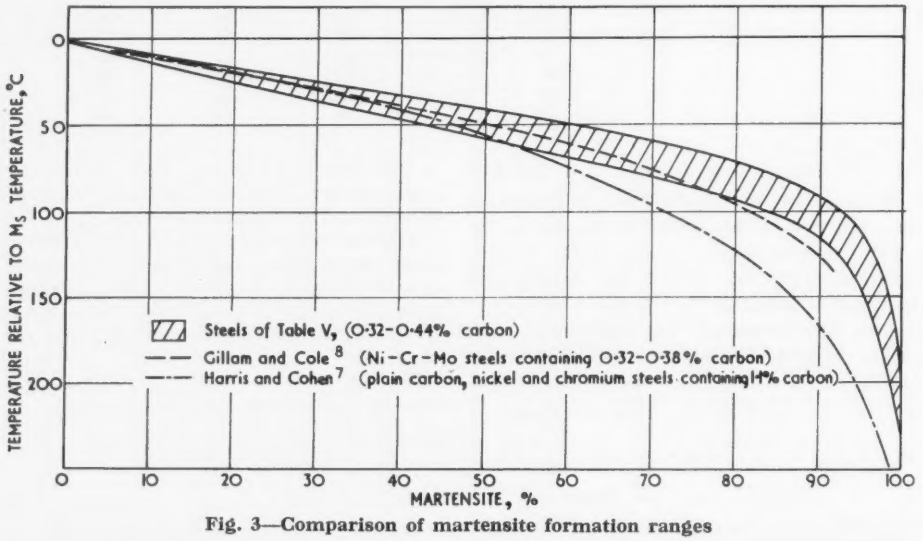


Fig. 3—Comparison of martensite formation ranges

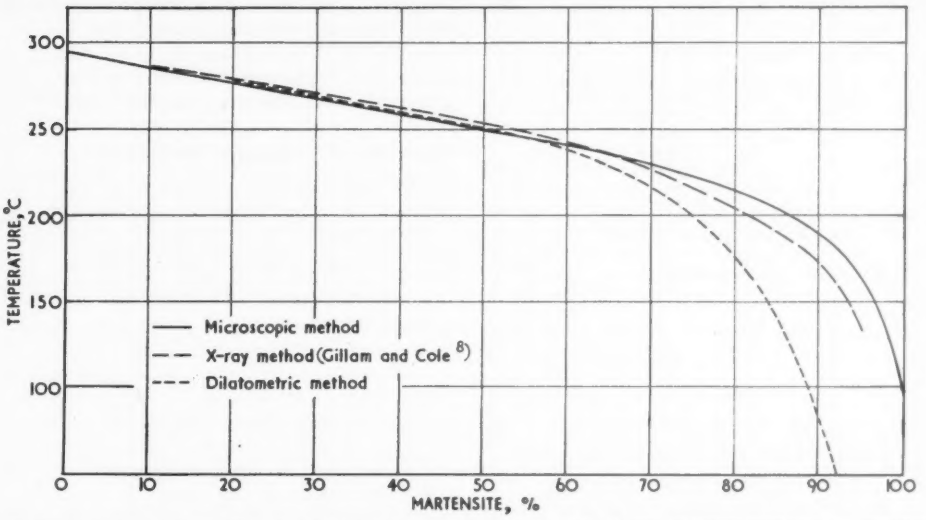


Fig. 4—Comparison of results of microscopic, dilatometric, and X-ray determinations of martensite formation ranges of a B.S. En 30*B* steel (steel 26)

martensite occurred rapidly with fall of temperature at a uniform rate of approximately 1% per ° C but at lower temperatures the reaction rate was retarded. The extent of the transformation range for all steels was between 200° and 230° C. These features are illustrated by Fig. 3 in which the progress of the reaction is plotted against temperature, the latter being measured relative to the M_s temperature.

It follows that equation (1) can be rewritten in the general form:

$$M_x\%\ (°\,C) = K - 474C - 33Mn - 17Ni - 17Cr - 21Mo \quad \ldots\ldots(2)$$

where $K = 561$ for M_s
$K = 551 \pm 3$ for M_{10}
$K = 514 \pm 9$ for M_{50}
$K = 458 \pm 12$ for M_{90}
$K = 346 \pm 15$ for M_f

The possible errors quoted for the various values of K represent the width of the scatter band portrayed in Fig. 3 and do not include those of the basic formula (Table VII).

Equation (2) is based on a study of steels lying within the following range of chemical composition:

Carbon	0·32–0·44%	Chromium	0·28–1·44%
Manganese	0·44–1·38%	Molybdenum	0·10–0·51%
Nickel	0·74–4·23%		

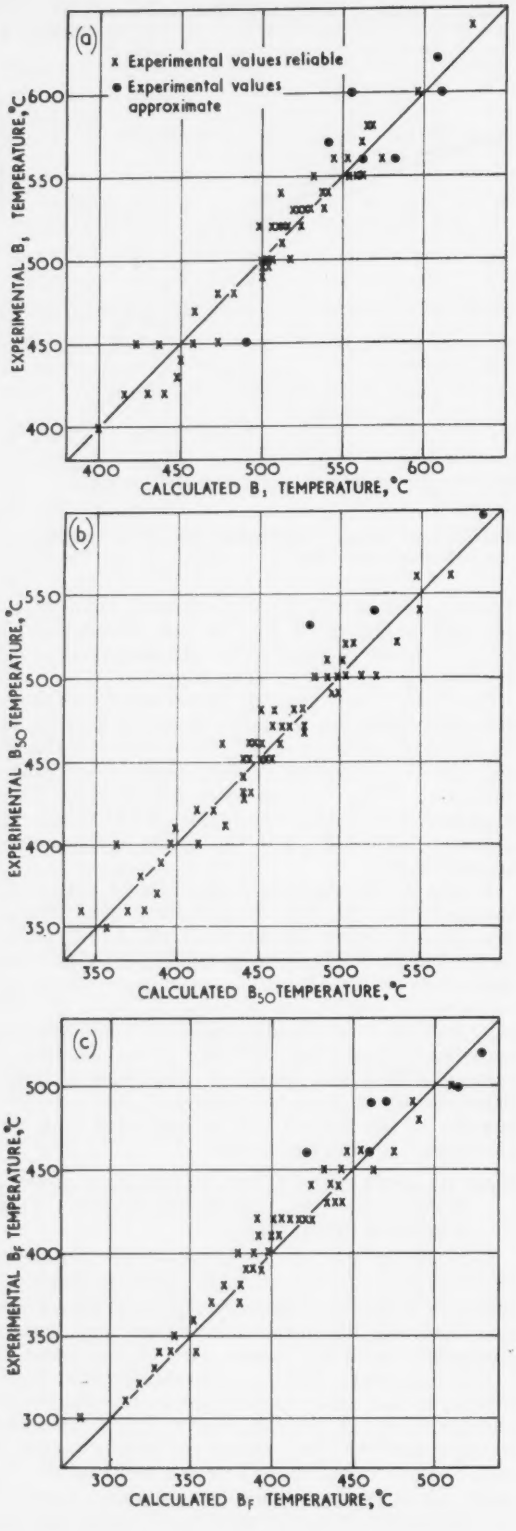
Grange and Stewart[7] have suggested that the extent of the M_s–M_f range increases with increase of carbon content, but as the carbon contents of the steels studied were limited to the range 0·32–0·44%, the present investigation did not confirm this effect of carbon. Harris and Cohen[8] noted a similarity in the rates of martensite formation in plain carbon, nickel, and chromium steels containing 1·1% carbon (Fig. 3). The formula they derived indicated that these steels have an M_s–M_f temperature range of approximately 300° C. This is greater than that of the steels of lower carbon content studied in this investigation. On the other hand, the M_s–M_f ranges reported by Payson and Savage[1] are, in general, in fair agreement with those recorded in this investigation and, furthermore, the data obtained by Payson and Savage are in accord with the suggestion that M_s–M_f ranges are not significantly affected by alloy content.

Using the X-ray method, Gillam and Cole[9] established the martensite formation ranges of B.S. En 24, 26, and 30*B* steels (steels 17, 21, and 26 of Table I), and noted a similarity in their rates of martensite formation. Their average curve for the three steels is plotted as a broken line in Fig. 3 and shows fair agreement above M_{70} with the results of the present investigation.

In Fig. 4 a comparison is provided of the results obtained from the B.S. En 30*B* steel (steel 26) by the microscopic and dilatometric tests of this investigation and those obtained by Gillam and Cole using their X-ray method. The martensite-formation/temperature curves are identical between M_s and M_{60}, but at lower temperatures discrepancies are apparent. These may be owing to stabilization of austenite, since the degree of completion of transformation at a given temperature increases with increase in the rate of cooling associated with the particular experimental method.

Part II—INFLUENCE OF CHEMICAL COMPOSITION ON PROGRESS OF THE BAINITE REACTION

In view of the success achieved in correlating chemical composition and martensite formation temperatures, it was decided to attempt a similar correlation between chemical composition and certain characteristics of the upper part of the range of bainite formation. This range was chosen since, superficially, it has some resemblance to the martensite reaction, although the initial rate of transformation is finite and the final extent of transformation is temperature dependent. There is a temperature (B_s) above which bainite will not form; there is a temperature above which more than 50% of bainite will not



(*a*) B_s temperature (*b*) B_{50} temperature (*c*) B_f temperature

Fig. 5—Comparison of calculated and experimentally determined bainite formation temperatures

form (B_{50}), and there is a temperature below which transformation will reach completion (B_f). Thus the B.S. En 30*B* steel has a B_s temperature of 420° C and a B_{50} temperature of 350° C (Fig. 1). The B_f temperature of this steel is just below its M_s temperature.

Experimental Procedure and Results

The steels studied were those of Table I. Their isothermal transformation characteristics in the bainite range were determined, generally by the dilatometric method supplemented by microscopic tests, but a few were determined entirely by the microscopic method. The B_s, B_{50}, and B_f temperatures of the steels were derived from these diagrams and are listed in Table VI. These temperatures could be assessed reliably from those diagrams in which there was no appreciable overlap of the bainite and pearlite transformation ranges. The corresponding temperatures for the less highly alloyed steels, for which the two ranges overlap, could be determined only approximately in some cases. These have accordingly been presented in parenthesis in Table VI, and are distinguished from the more reliably defined temperatures in the diagrams.

DISCUSSION OF RESULTS

A statistical analysis of the data of Table VI using the method of least squares revealed that they conformed to the following general equation within the limits indicated in Table VII:

$$B_x\%\ (°C) = K' - 270C - 90Mn - 37Ni - 70Cr - 83Mo \quad \ldots\ldots(3)$$

where $K' = 830$ for B_s, 770 for B_{50}, 710 for B_f. Using this equation the B_s, B_{50}, and B_f temperatures of steels lying within the following range of composition can be calculated with 90% confidence to within ± 25° C of the experimentally observed value:

Carbon	0·1–0·55%	Chromium	Trace–3·5%
Manganese	0·2–1·7%	Molybdenum	Trace–1·0%
Nickel	Trace–5%		

Calculated values are compared with experimentally determined values in Figs. 5*a–c*.

A comparison of equations (1) and (3) reveals that carbon depresses B_s, B_{50}, and B_f temperatures more markedly than any of the common alloying elements, but its effects on these temperatures are markedly less than its corresponding effect on M_s temperatures. Alloying elements, on the other hand, depress B_s, B_{50}, and B_f temperatures more markedly than they affect M_s temperatures. Differences are also apparent between the relative effects of the various alloying elements on martensite and bainite formation temperatures. It is also noteworthy that the data of Table VI reveal no evidence of the extent of the B_s–B_f range, being dependent on carbon content at least over the range 0·1–0·55%.

SUMMARY AND CONCLUSIONS

Consideration has been given to possible sources of error in the Greninger and Troiano method for the determination of martensite formation ranges. It has been demonstrated that although the method is

adequate for the determination of the M_s temperatures of a wide variety of steels, its suitability for the study of rates of formation of martensite below the M_s temperature is restricted to steels of relatively high hardenability because of the nucleating effect of martensite on bainite formation.

The martensite and bainite transformation characteristics of a wide variety of steels were determined and from a consideration of these, empirical formulæ have been derived relating composition and certain transformation temperatures.

M_s and B_s temperatures of steels within the following limits of chemical composition

Carbon	0·1–0·55%	Chromium	Trace–3·5%
Manganese	0·2–1·7%	Molybdenum	Trace–1·0%
Nickel	Trace–5%		

can be calculated to within ± 20–25° C with a 90% certainty from the following equations:

$$M_s\ (^\circ C) = 561 - 474C - 33Mn - 17Ni - 17Cr - 21Mo$$

$$B_s\ (^\circ C) = 830 - 270C - 90Mn - 37Ni - 70Cr - 83Mo.$$

The B_{50} and B_f temperatures of steels within the same range of chemical composition are related to B_s temperatures by the following simple relationships:

$$B_{50}\ (^\circ C) = B_s - 60$$
$$B_f\ (^\circ C) = B_s - 120$$

The martensite formation ranges of eleven steels of relatively high hardenability and having carbon contents between 0·32% and 0·44% conformed to the following relationships:

$$M_{10}\ (^\circ C) = M_s - 10$$
$$M_{50}\ (^\circ C) = M_s - 47$$
$$M_{90}\ (^\circ C) = M_s - 103$$
$$M_f\ (^\circ C) = M_s - 215$$

Over the range M_s–M_{70}, the amount of martensite formed increased linearly with decrease of temperature, but below M_{70} the rate of formation decreased progressively with decrease of temperature.

Acknowledgment

The authors wish to record their indebtedness to The Mond Nickel Company, Ltd., for permission to publish this paper.

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Thirteenth Century Smelting Residues from Kirkstall Abbey

By R. Haynes, B.Met., Ph.D., A.I.M.

SYNOPSIS

Residues from the smelting of bronze, iron, and lead have been found and dated to the thirteenth century, and are described and discussed. A suggestion is made why bronze smelting was practised in preference to copper and tin smelting followed by alloying. 1180

Introduction

THE RESIDUES were discovered in a trench beneath the floor of the warming house of Kirkstall Abbey, near Leeds, during excavations in 1952.[1] A 2-in. dia. lead pipe, that had run from a cistern to a monastic bath, lay at the bottom of the trench, which had been filled with a variety of deposits. These deposits included pottery, charcoal, and the smelting residues, which are believed[1] to be "*the sweepings of smelting fires which cannot have been far off.*" The lead pipe had been installed during the thirteenth century and the residues are ascribed to the same period.

Information about these residues is an addition to the limited knowledge about metallurgy in the Middle Ages in England. The residues from bronze, iron, and lead smelting operations are described and discussed.

EXPERIMENTAL RESULTS AND DISCUSSION

The analyses recorded are representative of the samples and, unavoidably, all the samples were small. They should not be regarded as accurate representations of the compositions of the materials smelted in the thirteenth century.

The Copper–Tin Residue

The residue consisted of bright-green lumps of earthy material (similar in colour to malachite) in which lumps of wood charcoal were embedded. Below the surface layer the material was a very dark red colour and gave a brown 'streak.' A few very small pieces of bronze foil were associated with the material.

Large pieces of charcoal were removed from the material before it was crushed and ground for analysis. The product consisted of a mixture of dark-grey powder (89·5%) and small hard metallic particles of irregular shape (10·5%).

Manuscript received 1st February, 1955.

Dr. Haynes, formerly Assistant Lecturer in Metallurgy at Leeds University, is now Technical Officer with Imperial Chemical Industries Ltd., Metals Division, Birmingham.

The analysis of the powder, after drying at 170° C, was

Cu	38·46%	Pb	2·81%
Sn	10·74%	FeO	1·15%
(SnO_2	13·65%)	CaO	0·3%
SiO_2	26·41%	S	0·10%
MgO	3·5%	Loss on ignition	4·34%
Al_2O_3	2·91%		

Copper and tin were present as oxides and the loss on ignition was due to carbonaceous material, etc.

The metallic particles, whose compositions were variable, were divided into two groups: white particles, which were most numerous, and red particles.

Compositions of white particles fell within the limits:

Cu, %	Sn, %	Pb, %	Fe, %
65·1–69·5	27·5–30·3	0·9–1·0	<0·75

Spectrographic analysis showed the presence of traces of silver, bismuth, antimony, and zinc. Red particles were richer in copper and one example contained 16% tin.

Micrographic examination showed that the white particles consisted of white crystals in an eutectic matrix and contained numerous blowholes. Red particles were composed of copper–tin ($\alpha + \delta$) eutectoid in a matrix of heavily cored copper–tin (α) solid solution and were very porous.

Metallic particles with an ' as-cast ' structure and lumps of charcoal embedded in the material indicated that the material was partially smelted charge. The high ratio of tin to copper (approx. 1 : 4) showed that smelting was for bronze and that the presence of tin was not fortuitous. The bronze produced would be high in tin and would be hard and possibly brittle. Metal of about this composition is used for bells,[2] and there is evidence of bell founding during this period.[3]

The metal was produced by reduction smelting, probably in some form of simple shaft furnace employing blast.[4] Experiments using (lumps of) wood charcoal in a shaft of 9-in. square cross-section and 10 in. deep showed that a temperature of about 1150° C could be attained using natural draught, and using a few cubic feet of forced air per minute (without natural draught) 1350 ± 20° C could be maintained easily, temperatures up to 1450° C being recorded. A small amount of residue was smelted in this furnace and it yielded a bronze of composition Cu, 92·3%; Sn, 5·96%; Pb, 0·49%, Fe, 0·03%. A mixture of powdered material and powdered charcoal was heated in a crucible at 1300–1400° C for a few hours, but reduction was unsatisfactory. It appeared that reduction was accomplished most satisfactorily by a gaseous reducing agent, i.e. carbon monoxide formed in the shaft furnace, and not by direct reaction between the oxides and solid carbon.

The high copper and tin contents and the very low sulphur content indicated that high-grade oxidized ores were used, although the ores probably underwent some simple form of beneficiation before smelting.[5, 6] High-grade oxidized copper ores containing 11–39% copper have been found in Arizona,[7] and the ancients probably worked ores containing 10–20% copper[6]: these were of the same order of magnitude as the copper content of the material. The very low sulphur content could not have been achieved by roasting sulphide ores by the methods then available; indeed, it would be difficult by modern methods.

From the material available, it seemed that no flux was used, and that a slag containing about 75% silica would be formed. This would have a fairly high fusion point and would lead to high metal loss, although the amount of slag would be small.

It is noteworthy that bronze was produced by the reduction of a mixture of the oxidized ores of copper and tin. The composition of the bronze could have been controlled better by reducing the metals separately and melting them together, for copper was known from antiquity and tin was produced by the Egyptians as early as 600 B.C.[8] and by the Romans.[9] The reason for smelting mixed ores at so late a date is not clear, but a higher recovery of tin may have been obtained by smelting tin ore with copper or copper minerals.

Tin oxide is amphoteric and can enter a slag either as a basic oxide or an acidic oxide, depending on the composition of the slag. Consequently the loss of tin in the slag is likely to be high if there is little or no control of slag composition and if the smelting temperature is fairly low. In modern tin-smelting practice the first smelting is carried out at 1200–1300° C and slag is produced which usually contains 10–25% tin. This slag is subsequently retreated at a higher temperature, 1400–1500° C, with suitable fluxes to recover tin, and the final slag contains 1–3% tin.[10] In early times it was not considered worthwhile to re-treat slags, and slags have been found containing more than 20% tin.[11] Tin smelting was a very inefficient process and would probably be avoided whenever possible.

If tin ore was smelted with copper or copper ore[12] the tin and copper would alloy.[4] The chemical potential of the tin in the alloy would be small compared with that of pure tin and the tendency of tin to enter the slag would be reduced. Thus smelting of mixed copper and tin ores would probably lead to a better recovery of tin. This may account for bronze smelting in preference to smelting copper and tin separately and subsequent alloying, since the majority of tin was used in bronze.[13] Removal of a product of reaction at a low chemical potential made possible the production of brass in antiquity[14] and, more recently, the production of aluminium as a copper–aluminium alloy in the now obsolete Cowles process.

The bronze foil was present in very small quantity (< 1·3 g by weight) and was badly corroded. Analyses of the three pieces were as follows:

	1.	2.	3.
Cu	89·15%	87·10%	87·30%
Sn	6·07%	4·21%	4·82%
Zn	4·89%	N.D.	6·44%
Pb	1·17%	N.D.	0·51%

Traces of antimony and bismuth also were detected spectrographically in sample 3.

The microstructure of foil 3, which was about 0·0166 in. thick, consisted of small twinned grains of copper–tin solid solution with tiny globules of a second constituent, probably lead and/or oxidized material, dispersed uniformly throughout the metal. Some of the grains of solid solution showed strain markings. This structure indicated that the foil was made by alternate cold-working (hammering) and

annealing and that the final operation was annealing. The erratic distribution of the strain markings suggested that probably they had been caused by subsequent deformation of the foil.

The foil was obviously of greater age than the rest of the material examined, and was added to the smelting charge for reclamation.

The Iron Residue

This material was a dark, porous, cindery mass which was powdered and dried at 170° C before analysis. The composition of a sample was:

SiO_2	73·58%	CaO	1·66%
Al_2O_3	14·28%	MgO	1·08%
FeO	5·78%	Pb	0·20%
Cu	2·53%	(= PbO	0·22%)
(= CuO	3·16%)	S	0·018%

The residue was a slag from iron smelting. Probably no fluxes were used since the silica content was high and the lime content very low. Powdered material fused into a porous mass at temperatures greater than 1250° C and the maximum working temperature in the process must have been at least 1300° C.

The monks at Kirkstall had ironstone mining rights at Seacroft, near Leeds,[15] but no analyses of ore from Seacroft are known.[16] Thus it was impossible to compare the compositions of slag and ore. Analyses of ore from the same bed, the ' Low Moor Ironstone,' at Bierley some ten miles to the south-west, were made before 1856.[17] With the exception of iron oxide, the major constituents of slag and ore were silica and alumina, and the SiO_2/Al_2O_3 ratio was approximately 5·1 for the slag and 2·5 for the ore,[17] and these are of the same order of magnitude. Other ores in the Northern Pennine orefield[18] had SiO_2/Al_2O_3 ratios up to about 8.

The copper content of the slag was unusually high, for British ironstones are practically free from it.[17] Probably smelting for iron and copper or bronze was carried out in the same furnace.

The apparent omission of fluxes in iron and possibly in bronze smelting may indicate a lack of knowledge of their use, although the use of fluxes was known to the ancient metallurgists.[19]

The Lead Residue

This consisted of metallic lead (76%) coated with greyish-white material (24%). The form of the material suggested that it was a small pool of metal which had been spilled and subsequently had become covered with oxidized material.

The metal had the composition:

Cu, %	Ag, %	Fe, %	S, %
0·20–0·63 (mean 0·37)	0·0085	0·004–0·01	0·004

Traces of antimony, bismuth, cadmium, and tin were detected spectrographically.

The metal was of high purity and the only impurity present in appreciable amount was copper. Its copper content was variable because copper and lead are almost immiscible in the liquid state and this would cause segregation. The presence of only traces of other impurities indicated that the metal had been refined; copper and bismuth are the only base metals which are not removed in the refining of lead by controlled oxidation, i.e. the softening process. The silver content was very low and showed that the lead had been desilvered by cupellation. Forbes[20] stated that "*the Romans could extract (silver) down to* 0·01% *or even* 0·002% *in some cases*," and "*Agricola mentions that in his day the limit of extraction was* 0·008% *of silver*." Thus the silver content, 0·0085%, was close to the limit of extraction attainable at that period. This metal probably came from a melting operation.

After drying at 170° C, this composition of the powdery material was:

PbO	49·25%	MgO	0·9%
SiO_2	33·19%	CaO	0·40%
Al_2O_3	6·19%	CuO	0·52%
FeO	1·87%	S	0·013%
Loss on ignition	7·19%		

Loss on ignition was due to carbonaceous material, etc.

This composition suggested that the material was a mixture of oxidation product (PbO) and earthy material and was an example of the composition of an encrustation formed on a buried lead object.

Acknowledgments

The work described in this paper was carried out in the Department of Coal Gas and Fuel Industries with Metallurgy, Leeds University. The author wishes to thank Dr. D. E. Owen, Director of Leeds City Museum, for permission to publish the work and for helpful discussions during the course of it.

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Thermal Changes in Steels as shown by Resistivity

By G. Bullock, B.Sc., M.Sc.Tech., Ph.D., A.I.M.

SYNOPSIS

This work concerns principally the development of a method for determining precise apparent electrical resistivity values at high temperatures so that the results may be plotted in a manner analogous to inverse-rate thermal curves, to which they are intended to be supplementary. Experimental values obtained principally at temperatures in the range 650–950° C are given for several commercially pure iron–carbon alloys containing between 0·02% and 1·15% carbon. 1194

Introduction

PHASE AND FUNCTIONAL energy changes, such as magnetic and order–disorder changes, have been examined in the past using electrical techniques. It is desirable where possible to obtain resistivity values and in the case of metals these have been determined in the main using wire specimens. The term 'apparent resistivity' has been used to indicate a value calculated using high-temperature resistance values and dimensions measured at about room temperature.

Errors which arise due to lack of uniformity of cross-section throughout the length of the wire and to inaccuracy in measuring the small diameter of the wire can be reduced considerably by using an accurately machined rod as specimen. This specimen is usually arranged in the form of a four-terminal resistance and has a low resistance which is commonly measured by either a Kelvin double-bridge or a potential fall method. The former is rather unsuitable for high-temperature work, however, because uncertain resistance effects may be introduced in the bridge arms connected to the specimen as they are exposed to high temperatures. The potential fall method avoids these uncertainties, but it is necessary to pass a large current through the specimen in order to produce a suitable potential difference. In the present work a current of 20–30 A has been used, which causes a potential drop of about 10–15 mV in the specimen at 800° C.

High-temperature resistance data and, in some cases, resistivity values have been reported by several authors[1–14] for irons and steels. Ribbeck,[10] Jaeger,[11] and Pallister[12] have determined apparent resistivity values for iron of various degrees of purity (greater than 99·9% iron), while Saldau,[6] Honda and Ogura,[7] Honda and Simidu,[8] and Powell and Hickman[9] have reported values for commercial purity iron–carbon alloys. The latter workers have also reported values for a number of commercial alloy steels.

Weber[15] has reported resistivity results for low-melting-point metals and alloys such as the binary alloys of lead and tin, and of bismuth and tin. Saldau[16] has reported values for a series of gold–cadmium alloys, Somerville[4, 17] has examined nickel, Nichrome, aluminium, silver, gold, copper, Manganin, constantan, and Advance, and Harrison[3] has given values for nickel and copper.

Electrical resistance measurements have been used for examining functional energy changes such as the order–disorder change in β-brass by Haughton and Griffiths,[18] and Matsuda,[19] in copper–palladium alloys by Taylor,[20] in iron–aluminium alloys by Sykes and Bampfylde,[21] and Bennett,[22] and in nickel–chromium and nickel–chromium–aluminium alloys by Taylor and Hinton.[23] In addition, electrical resistance values have been used for studying the decomposition of martensite[24] and for determining the Wiedemann–Franz ratios for several metals.[25–29]

This survey of the literature revealed that a precise method for determining apparent resistivity values at small temperature intervals on heating or cooling, in a manner analogous to thermal curves, had been undertaken by Powell and Hickman[9] as part of a larger programme concerning electrical resistivities of a number of carbon and alloy steels up to 1300° C.

A rod specimen 0·5 cm dia. and 10 cm working length was used and resistivity values were obtained on heating (but apparently not on cooling) at about 3° C/min by the potential fall method. Chromel wires welded to the specimen served as leads for determining the potential drop and in order to eliminate the effects of spurious thermal e.m.f's in this circuit, which arise especially near transformation points, this sequence was followed:

(1) The specimen temperature was measured
(2) Simultaneous observations of the potential drop across the specimen and the standard resistance were made
(3) Repeat of (2) with the current passing in the reverse direction through the specimen
(4) Repeat of (1).

A rise in temperature of about 3° C occurred during this sequence of observations and the data obtained before and after the reversal of current were averaged when evaluating the results, resistivity values being obtained at about 12° C intervals. This almost certainly eliminates errors due to thermal e.m.f's when the specimen is not undergoing a phase change, and even during phase changes it will be effective but probably to a lesser degree. It is difficult, however, to envisage a method which completely eliminates errors due to thermal e.m.f's, especially during phase changes, when resistivity values are determined for continuous heating or cooling. The method used by

Manuscript received 11th January, 1955.
Dr. Bullock is Lecturer in Metallurgy in the Faculty of Technology, University of Manchester.

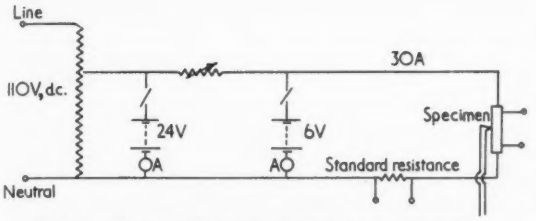

Fig. 1—Circuit diagram of two-stage stabilizer

Powell and Hickman[9] which is described above appears to be the most effective for this purpose.

Powell and Hickman plotted their results as large-scale graphs and reported numerical values after smoothing. In addition, increments of resistivity for 10° C intervals were plotted against temperature, thus giving curves similar to differential thermal curves such as the inverse rate. They believe that some of the small kinks in their differential resistivity curves may reflect the departure of an experimental point from the true curve of resistivity against temperature.

One of the objectives of the present work has been to obtain differential resistivity/temperature curves which do not show the presence of the kinks encountered by Powell and Hickman. No doubt this could have been achieved relatively easily by using a high-resistance specimen such as a thin wire. However, this would result in a loss of absolute accuracy. It was intended to avoid this loss as far as possible and hence a rod specimen has been used.

EXPERIMENTAL

The circuit diagram of the heavy current supply to the specimen is shown in Fig. 1, and because of the facilities available it was necessary to adopt a standard voltage-stabilizing arrangement. Any variation in the circuit current due to variation of mains voltage is compensated by changes in the discharge currents of the two accumulators. The discharge voltage of an accumulator, however, changes with discharge current and the compensation is not perfect. The degree of compensation can be quite high, provided that the dynamic or differential resistance of each stabilizing stage is small (i.e. $\Delta E/\Delta I \rightarrow 0$), a condition which is achieved by using accumulators with thin plates and high acid concentration. In the circuit shown in Fig. 1, a change in mains voltage of 1 V causes the current through the specimen to change by 1 part in 18,000.

It is important that the dynamic resistance of the two stabilizing stages should be as small as possible and that the circuit resistance should be constant except for smooth variations due to change of the specimen temperature. Temporary joints were avoided except for the switches in the stabilizing stages, and the connecting wire in the circuit was 0·25 in. dia Advance, which has a small temperature coefficient of resistance.

The current and potential leads and the thermocouple were welded to the specimen, which was about 6 in. long by 0·5 in. dia., as shown in Fig. 2. The current leads were Advance, the potential leads were either iron or platinum–13% rhodium alloy and the thermocouple was chromel/alumel or platinum/platinum–10% rhodium, depending on the specimen under observation.

The electrically-heated furnace was about 36 in. long with a 3-in. bore. An earthed nickel cylinder acted as a temperature equalizer over the middle third of the furnace bore. The specimen with its attendant current, potential, and thermocouple leads was enclosed in a long silica tube and in the earlier experiments a nitrogen atmosphere was used to prevent oxidation of the specimen. The apparatus was later modified so that the specimen could be heated *in vacuo* (about 0·001 mm mercury).

The specimen was heated and cooled at about 1–1·5° C/min by varying the voltage applied to the furnace linearly with respect to time. This voltage was obtained from a Variac whose commutator was rotated uniformly and the linearity was subject to the limitations imposed by the finite number of turns on the winding.[30] The large thermal capacity of the furnace smoothed out the irregularities due to the finite voltage increments of the Variac output.

In an auxiliary experiment carried out at 25° C before the experiment proper, the potential fall along the specimen was compared with the potential difference between two knife-edges at a known distance apart. This enabled apparent resistivity values to be computed for high temperatures assuming geometrical similarity of the specimen.

The potential differences across the standard resistance and the specimen and the thermocouple e.m.f's were measured at intervals of 0·1 mV or less, using three defined-interval potentiometers. It was not practicable to obtain simultaneous measurements directly, and so the values were recorded on a modified paper-tape chronograph giving a permanent record. Results which differ negligibly from simultaneous values have been obtained by simple interpolation and hence after correcting for thermal e.m.f's, which are measured in control experiments, apparent resistivity values have been calculated.

Errors due to thermal e.m.f's were not eliminated by making observations before and after reversing the current through the specimen. For reasons which will be discussed later it was decided to measure the thermal e.m.f's in control experiments. Observations were made in the experiment proper when the specimen was being heated or cooled between about 650° C

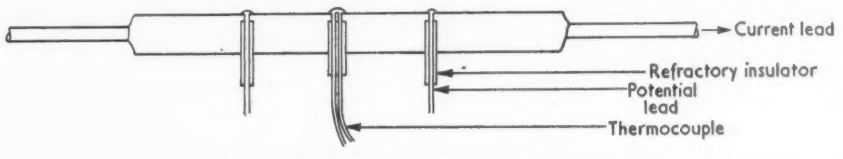

Fig. 2—Electrical connections to specimen

Table I
ANALYSIS OF MATERIALS

	C, %	Si, %	S, %	P, %	Mn, %	Ni, %	Cr, %	N, %
Basic OH	0·02	0·007	0·017	0·018	0·027	Trace	Nil	0·005
Acid OH	0·265	0·10	0·033	0·023	0·63	Trace	Nil	...
Acid OH	0·49	0·15	0·032	0·034	0·69	0·01	Nil	...
Acid OH	0·83	0·215	0·015	0·018	0·69	0·22	0·05	...
Crucible	1·15	0·098	0·008	0·028	0·27	Trace	Nil	...

and a temperature 50–100° C above the A_3 point. By interrupting the current through the specimen, thermal e.m.f's were measured at the maximum and minimum temperatures on heating and on cooling. In addition, the experiment proper was repeated without the current flowing through the specimen and the thermal e.m.f's were measured throughout the entire temperature range. The specimen thermocouple was also checked against a laboratory standard thermocouple to determine whether any change in calibration had occurred.

MATERIALS

The materials used in this investigation were selected from a range of commercial irons and steels. They were relatively free from non-metallic inclusions and are typical of material produced in good iron and steelmaking practice. The Armco iron was manufactured by the basic O.H. process and contains a number of inclusions which are so small that no recognizable characteristics can be seen when using a microscope fitted with an oil-immersion objective. The 0·26%, 0·49%, and 0·83% carbon steels are high-quality acid O.H. steels and the 1·15% carbon steel is a Huntsman crucible steel. These steels are relatively free from inclusions except that they contain a small number of manganese sulphide particles. The analyses of these materials are given in Table I.

DISCUSSION

The present work supplements that of Powell and Hickman[9] but differs in the following respects:

(i) A shorter specimen of greater cross-sectional area has been used and a larger current was passed, giving a potential drop about three or four times greater than that obtained by Powell and Hickman for comparable materials. This greater potential drop also serves to reduce the relative magnitude of thermal e.m.f's in the specimen-measuring circuit

(ii) The elimination of errors which arise as a result of thermal e.m.f's in the specimen measuring circuit, by making observations before and after reversing the current through the specimen, was not undertaken.

The low circuit resistance necessary to pass 20–30 A from a stabilized 6-V supply militated against the use of temporary joints such as switches. Several switches had been tried but they caused considerable intermittent variations in the current passing through the specimen. As it was intended to plot curves of the rate of increase of resistivity with respect to temperature ($\Delta\rho/\Delta\theta$) against temperature θ using the experimental values, without previous smoothing of the resistivity temperature curves, any intermittent variations of the current passing through the specimen could not be tolerated as they would have influenced the smoothness of the differential resistivity curves. On this account it was expedient not to reverse the current through the specimen.

However, it was also intended to obtain resistivity values as precise as possible, using the potential fall method, which involves rod specimens of low resistance and a large exciting current. The latter may produce a potential drop in the specimen of only a few millivolts, and thus thermal e.m.f's in the measuring circuit may constitute a major source of error. The method of reversing the current through the specimen and making duplicate observations is the customary way of eliminating such errors but in the present work, for reasons stated previously, it was decided not to adopt this method. Therefore attempts have been made to eliminate or reduce the magnitude of the thermal e.m.f's; e.g. a temperature gradient along the specimen together with the use of potential leads of material which has a relatively high thermoelectric power with respect to the specimen, may cause a resultant thermal e.m.f. in the potential measuring circuit. While it ought to be possible to eliminate thermal e.m.f's originating in this way, it is not possible to eliminate those which arise in the specimen as a result of a transformation. In the present work attempts to measure the thermal e.m.f's in separate control experiments have been undertaken, but as a means of obtaining precise resistivity values this method is doubtless inferior to that adopted by Powell and Hickman.[9]

In practice it was found that the magnitude of thermal e.m.f's in the specimen-measuring circuit was reduced considerably by using pure iron instead of Nichrome potential leads. The thermal e.m.f's which occurred in a eutectoid carbon steel specimen using iron potential leads is shown in Fig. 3. In general, their magnitude is small except when the iron leads undergo the A_3 transformation. In the present work, iron potential leads have only been used for specimens

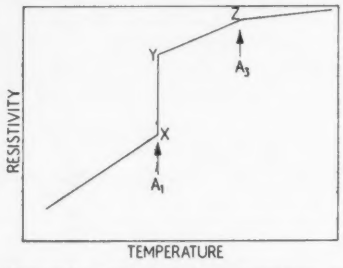

Fig. 3—Schematic resistivity/temperature curve for a hypothetical steel

which have not been heated to a temperature high enough to cause the leads to undergo the A_3 transformation (Table II). For the Armco iron specimen only, platinum–13% rhodium leads have been used as this alloy has a thermo-electric power with respect to iron much lower than Nichrome. Thermal e.m.f's resulting from the A_3 transformation in the Armco iron specimen are shown in Fig. 4.

The absolute accuracy of some of the present results has been influenced by factors such as nitriding of the base-metal thermocouples, spurious thermal e.m.f's in the specimen-measuring circuit due to nitriding of the potential leads, the presence of a small temperature gradient of between 1° and 2° C along the specimen, and thermal e.m.f's due to transformations occurring in the specimen. Control experiments in which thermal e.m.f's have been measured and check calibrations of the thermocouple indicate that at temperatures at which the specimen is not undergoing a phase change, the absolute accuracy of the results is probably better than 1%. In these circumstances, the thermal e.m.f's were less than 0·1% of the potential drop in the specimen in the experiment proper, but during the A_1 and A_3 transformations, thermal e.m.f's occurred rather greater than this value. An exception was noticed during the Ar_1 transformation in the 1·15% carbon steel when the thermal e.m.f's reached 0·4–0·5% of the potential drop in the specimen in the experiment proper. This was the only alloy which was not heated to a temperature high enough to be transformed completely to austenite. On cooling, the Ar_1 transformation did not show a degree of thermal hysteresis comparable with that for the other alloys and it also extended over an appreciable range of temperature. These factors may have influenced the magnitude of the thermal e.m.f's encountered during the Ar_1 transformation in this alloy.

When checked at 600° C the calibrations of those chromel/alumel thermocouples which had been heated in nitrogen were found to have changed by 0·3–0·5%, which, together with errors due to thermal e.m.f's in the specimen-measuring circuit, brings the total error in the absolute accuracy of the results to a value in the region of 1%. In general the accuracy of the later work was found to have been improved by using noble-metal thermocouples with the specimen in nitrogen or *in vacuo*.

A factor which may influence the resistivity values at 25° C given in Table III is the interlamellar spacing of the pearlite. Labib[31] found for the eutectoid carbon steel used in the present work that an extremely fine pearlite has a resistivity about 3% higher than a coarse pearlite. Thus a change during the experiment of the pearlite interlamellar spacing in the specimens used in the present work may influence some of the results reported in Table III. The interlamellar spacing of the pearlite has been checked before and after each experiment by cursory microscopic examination and no major changes were observed. Therefore this effect may influence to only a minor extent the differences between corresponding values in Table III.

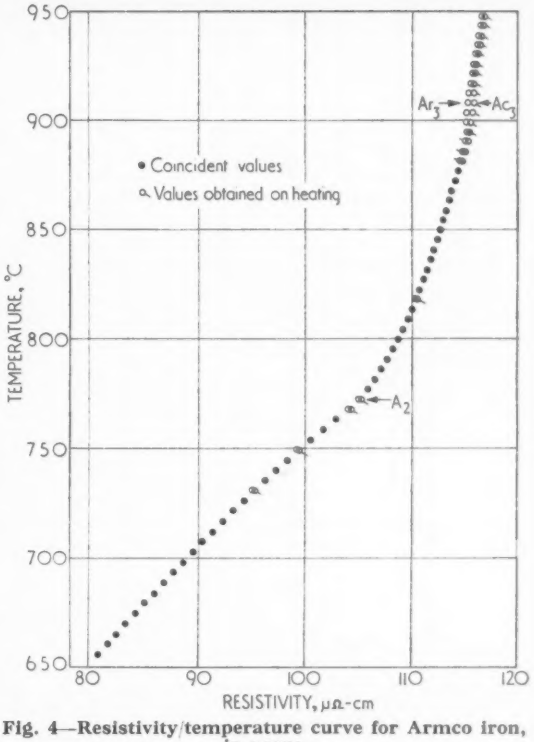

Fig. 4—Resistivity/temperature curve for Armco iron, *in vacuo*

The shapes of the resistivity/temperature curves in the present work agree in general with the findings of previous work for similar materials. Their smoothness is commensurate with a calculated value deduced from the performance characteristics of the components of the apparatus and could not be improved with the facilities available.

A schematic diagram of the resistivity/temperature curve for a hypoeutectoid steel is shown in Fig. 5. The discontinuity at XY is due to the eutectoid reaction, the change in resistivity ($\rho_X - \rho_Y$) being

Table II

A_3 TRANSFORMATION RANGE IN ARMCO IRON

	1·3° C/min	0·25° C/min
Ac_3	908–921° C	909–921° C
Ar_3	908–886° C	909–896° C

Table III

RESISTIVITY VALUES

Specimen	Resistivity at 25° C, × 10^{-6} Ω cm	
	Before Experiment	After Experiment
Armco iron	10·786	10·786
0·26% C steel	13·500	13·650
0·49% C steel	16·152	15·949
0·83% C steel	17·502	17·850
1·15% C steel	19·084	18·737
Armco iron (slow heating and cooling)	10·829	10·741

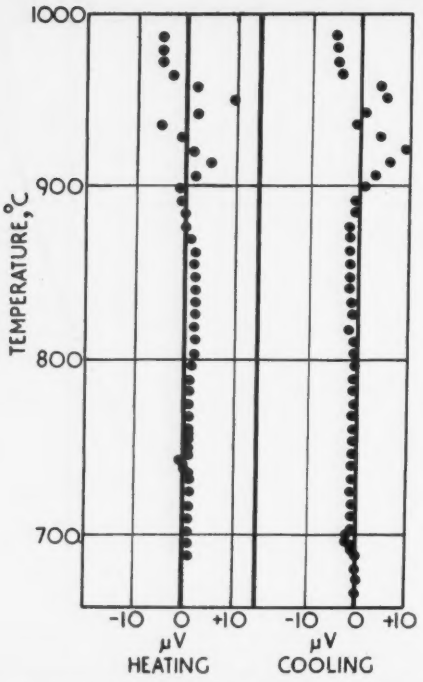

Fig. 5—Spurious thermal e.m.f's in specimen measuring circuit for eutectoid carbon steel specimen using iron wire as potential leads

dependent on the amount of pearlite present in the steel. The part of the curve between Y and Z is due to the absorption or liberation of ferrite by austenite. The exact shape is undoubtedly influenced by the A_2 transformation in ferrite, if the carbon content of the steel is such that the A_2 and A_3 change points are not coincident. The changes in slope in the experimental curves are not as abrupt as indicated in this schematic figure and in practice the exact position of the A_3 change point is not certain in every case. Generally, pronounced thermal hysteresis is shown by all the alloys investigated, the Ar_1 and Ac_1 change points occurring at about 700° and 740° C respectively. The Ar_3 and Ac_3 change points show similar degrees of thermal hysteresis.

The curves in Fig. 6 confirm work by Lampson[13] which had not been released for publication when the present work was carried out. They show that a decrease in resistivity occurs at the A_3 change point. The presence of the magnetic point, which is not subject to thermal hysteresis, at 768° C and the agreement of the resistivity results for heating and cooling appear to indicate a high degree of reproducibility.

The A_3 change point for the same Armco iron specimen was examined again, using much slower heating and cooling rates (about 0·25° C/min compared with 1·3° C/min previously) and the results are shown in Fig. 7. This was the third set of high-temperature observations on this specimen. The A_3 transformation ranges for two heating and cooling rates are given in Table II and from these values the A_3 change point appears to occur at 908–909° C, which is in good agreement with the commonly

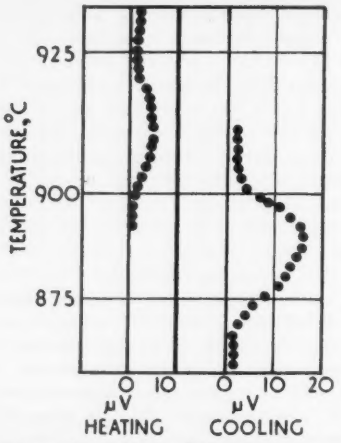

Fig. 6—Spurious thermal e.m.f's in specimen measuring circuit for Armco iron specimen with Pt–13% Rh alloy potential leads

accepted value and the recent findings of Pallister.[32] The resistivity values for Armco iron at 25° C are in reasonable agreement with one another. The values in Fig. 6 obtained at temperatures in the region of the A_3 change point differ by about 2% from the corresponding values in Fig. 7. Similar variations have been attributed by Pallister to permanent changes in the dimensions of the specimen due to exposure to high temperatures, and the volume changes accompanying the A_3 phase change. A change in specimen length of about 0·42% occurred in the present experiments when values were being obtained at slow heating and cooling rates in the region of the A_3 transformation.* After the experiment, the specimen exhibited a slight surface roughness but no surface film appeared to be present and when examined microscopically, the inclusions present appeared to be smaller and more evenly distributed than in the original material. A tentative explanation of the higher resistivity values shown in Fig. 7 is that an increase in solid solubility of some of the impurities present in Armco iron may have occurred on repeated exposure to high temperatures.

The resistivity/temperature curves for the remain-

* It is not known whether the change in length is permanent.

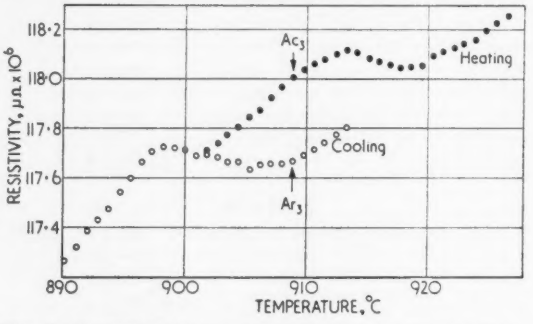

Fig. 7—Resistivity/temperature curves for Armco iron, *in vacuo*, using noble-metal thermocouple. Heating and cooling at about 0·25° C/min

ing alloys each show distinctive features. The curves for the Fe–0·26% C alloy show the presence of the A_1, A_2, and A_3 change points as separate features.

The curves for the Fe–0·49% C alloy show the A_1 change point very clearly but the A_2 and A_3 change points appear to occur simultaneously, even though the carbon content of this alloy is rather lower than the minimum of the range of alloys in which the A_{32} change point occurs. It appears that the electrical resistance method is not sufficiently sensitive to differentiate between the A_3 and A_2 change points in this alloy.

In the curves for the 0·83% C alloy, which contains a small amount of nickel and is actually slightly hypoeutectoid, the A_1 transformation overshadows the effects due to the liberation and absorption of proeutectoid ferrite. The heating curve shows that the proeutectoid ferrite appears to be absorbed by the austenite after the completion of the A_1 transformation whereas on cooling, the liberation of the ferrite and the austenite → pearlite transformation appear to occur simultaneously. The nickel in this steel probably causes an exaggeration of the thermal hysteresis usually encountered in steels.

The curves for the Fe–1·15% C alloy do not extend into the temperature region in which this alloy is totally austenitic. The A_{cem} change point occurs at 950–1000° C and with the apparatus used in this research it was not expedient to operate at such temperatures. Thus on heating, the proeutectoid cementite is not completely absorbed and on subsequent cooling, the A_1 transformation does not experience a degree of thermal hysteresis comparable with that for the other alloys. The A_1 transformation extends over an appreciable temperature range on cooling and appears to occur in two stages.

The inverse rate and the differential resistivity curves show a reasonable degree of correlation with one another although the former are subject to variations in the electrical supply voltage to the Variac control gear and hence all the features shown cannot be attributed to the thermal behaviour of the specimen. The variations in the heating or cooling rates of the specimens, due to changes in supply voltage, appear to have a relatively small effect on the differential resistivity curves. The change points of which the author is reasonably certain are indicated, while for those about which there is uncertainty, the appropriate indicating marks have been omitted.

The thermal and electrical measurements were made simultaneously on a rod-like specimen and the inverse rate curves are not as good as can be obtained using a small pear-shaped specimen. However, despite this limitation in the accuracy of the inverse-rate curves it is apparent that differential resistivity curves suffer from a defect similar to that of inverse-rate curves, in that the end of a phase transformation which occurs over a range of temperature is not always clearly indicated; e.g. the A_3 transformation in steels. Isothermal transformations, such as the A_1 in steels and functional energy changes such as the A_2 in iron, are clearly shown in differential resistivity curves.

CONCLUSION

An experimental method for obtaining precise apparent resistivity values has been developed and the numerical consistency of the results obtained is commensurate with the performance factors of the apparatus. It is extremely difficult to obtain even reasonable accuracy (i.e. ± 2–3%), especially when phase changes occur. The major difficulty in the present work originated because an attempt has been made to obtain simultaneously high numerical consistency (relative accuracy) and absolute accuracy using a specimen of large diameter, two aims which have tended to be mutually exclusive.

The thermal changes which occur in steels can in general be readily detected on continuous heating or cooling by electrical resistance methods. However, if resistivity values are desired, the method becomes tedious and involves intricate apparatus, compared with common inverse rate thermal techniques.

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Recording Techniques for Rolling Mill Operation Studies

By E. A. Chard, B.Sc.(Eng.), W. W. Hastings, B.A.Sc., and D. F. Nettell, B.Sc.(Eng.), A.M.I.Mech.E., A.M.I.E.E.

SYNOPSIS

Previous studies on rolling mills have depended on the participation of a number of observers. In order to eliminate human errors and to provide a continuous record, the techniques described in this paper have been developed.

The two instruments used, a modified teleprinter perforator and a 12-channel recording oscillograph, are complementary in their application and the use of one or the other in a particular application is governed by the information required. Some tests carried out with the 12-channel recorder, at a works, are discussed. 1231

Introduction

WHEN CARRYING OUT operation studies on primary rolling mills, records may be required of operations which occur frequently, but which last only a second or two and have a brief time interval between successive events. The information to be recorded may be of two kinds:

(i) Events: e.g. how many times an operation occurs during a process, the ON–OFF time for each operation, etc.
(ii) Quantities: e.g. the distance moved in a certain time, speed, acceleration, etc.

Recording systems which depend largely on the activities of human observers have disadvantages; errors are likely to arise due to observer fatigue, and where events occur rapidly, mistakes can be made with little time available to correct them. Also, the necessary number of observers must always be available. If, however, the desired information can be recorded electrically or mechanically on some form of tape or chart roll, then not only can human errors be eliminated but also the pattern of events can be studied as a whole.

Recent studies of rolling mill operation have led to the development of two recording techniques, one of which utilizes a modified commercial tape-perforator,[1] while the other uses a commercial 12-channel recording oscillograph. A brief account of each technique is given in this paper.

The tape perforating technique has already been used in a series of investigations into the operation of a slabbing mill; the results are not discussed here since a full account of these trials is published in the paper by Jones, Steer, and Dickerson.[2] The use of the 12-channel recorder has also been demonstrated on the same mill, and samples are given of information which can be obtained using this instrument.

PUNCHED TAPE TECHNIQUE

Description of Apparatus

The use of tape perforators for recording data automatically, in a form which lends itself to rapid analysis, has been fully developed by Nettell, and

Paper PE/R/60/55 of the Rolling Mill Plant Committee of the Plant Engineering Division of the British Iron and Steel Research Association, received on 4th October, 1955. The views expressed are the authors', and are not necessarily endorsed by the Committee as a body.

The authors were with the Association's Plant Engineering Division when this paper was prepared.

Fig. 1—Arrangement of tape perforator equipment

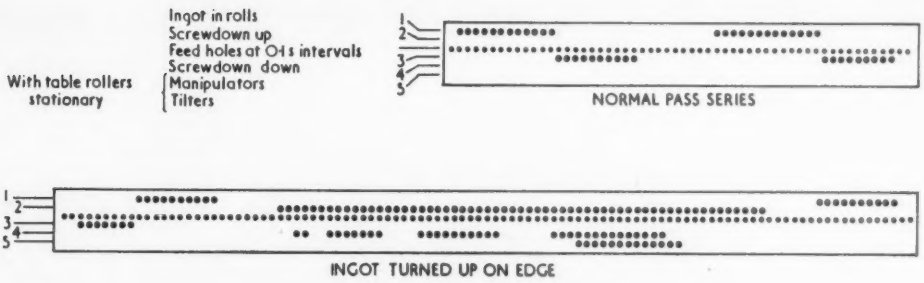


Fig. 2—Specimens of punched tape

only a brief résumé is given here of the equipment used in the application of this instrument for mill operation studies (*see* Fig. 1).

Tape Perforator

Characters representing letters, numerals, symbols, etc., are punched in a paper tape by a perforator which is controlled from a keyboard similar to that of a typewriter. As holes can be punched in five parallel tracks on the tape, any character can be represented in a code by the arrangement of holes and blank spaces in a line across the width of the tape. Successive characters will follow along the tape. An additional row of small holes in the tape are provided for engagement with the feed sprocket.

As a hole or space can appear in any five tracks in a line across the tape, then the number of combinations available, including zero, is 2^5—i.e. 32 different characters can be represented. By using the number of combinations available with two lines across the tape, 2^{10} (or 1024) different characters can be represented.

For recording data electrically, however, the keyboard control is inconvenient and a teleprinter has been modified by Nettell. In this, each punch is controlled by a post office relay which, when energized, sets the machine so that holes can be punched in the appropriate track. The operation of any mechanism can therefore be used to set a punch, and if punching occurs at regular intervals, the working time can be recorded as a row of holes on the tape.

The punching mechanism is operated by a camshaft driven by a small electric motor; the speed of the camshaft and the tape feed sprocket are controlled by a relay operated trip mechanism.

Time Base

The rate of perforation of the tape will depend on the rate at which the impulses are transmitted to the relay on the trip mechanism. A time-base unit is therefore used which can be set to give any required impulse frequency. The unit consists of a small synchronous motor driving a cam-operated microswitch through a variable gear. The impulse from the microswitch is transmitted to the trip relay on the tape perforator. Any required rate of perforation can be used, up to a maximum of 15/s; the usual commercial practice is to perforate at 7/s.

Control Box

The function of the control box is to collect the signals from the different items to be recorded, and to convert and transmit them in the form required to the perforator. For example, the operating time of some particular motion on a machine can be obtained by a signal taken from the contactors controlling the driving motor for that motion.

A 230-V a.c. supply is required for the time-base motor, 230 V a.c./d.c. for the perforator motor, and a 50-V d.c. supply for operating the relays in the control box, also the tripping magnet in the perforator, the latter voltage being obtained from rectifier unit supplied from the 230-V mains.

Operational Use

Examples of operations which might be recorded using the five available tracks are:

A 1. Ingot between main rolls
2. Screwdown movement
3. Manipulators working
4. Tilters working
5. Roller table working

B 1. Ingot between main rolls
2. Screwdown movement upwards
3. Screwdown movement downwards
4. Manipulators working
5. Tilters working

C 1. Ingot between rolls
2. Screwdown movement upwards
3. Screwdown movement downwards
4. Tilters working
5. Roller table working

Group *A* gives an overall picture of the main operations; group *B* enables the screwdown operation to be recorded in more detail; and group *C* favours the inclusion of the roller table in place of the manipulators. It is not intended, however, to stipulate the operations which should be recorded; the choice of records will be influenced by the type of mill, and the objectives of the investigation being carried out.

A method of obtaining the time during which the ingot is between the main rolls has been described by Jones,[2] in which an ordinary commercial photoelectric relay is used, mounted adjacent to the window in the mill housing on the free side and sighted just above the bottom main roll.

The driving motor times for the screwdown, tilting fingers, and manipulators can be obtained by taking a signal directly off the contactors controlling the driving motor of each motion. The leads from a spare pair of contacts on each of the appropriate contactor panels are taken to pairs of terminals on the control box.

The holes in the tape are always perforated at a

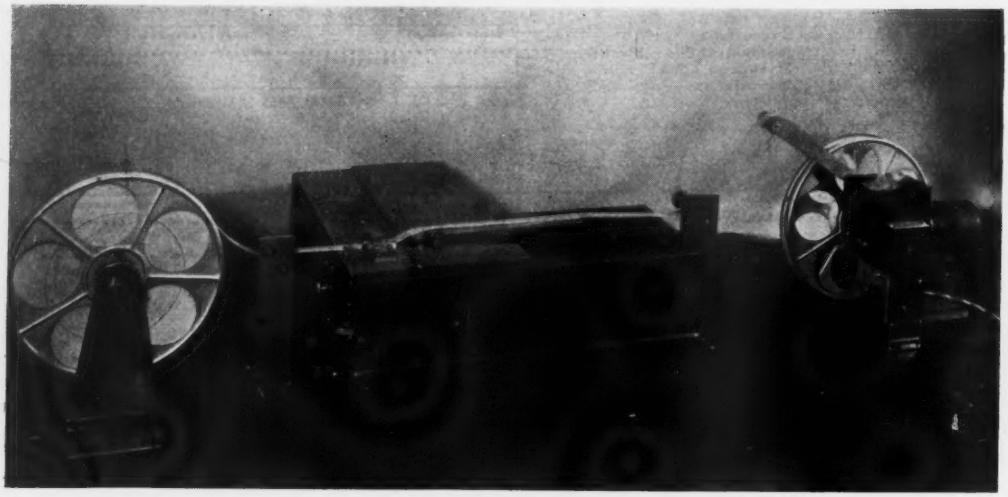


Fig. 3—Punched tape reader head

pitch of $\frac{1}{10}$ in.; in the tests so far carried out, a rate of perforation of 10 holes per second was adopted, and visual inspection and measurement are simplified since 1 in represents 1 s. Spools of tape are available in 800-ft lengths, providing about $2\frac{1}{2}$ h recording time.

Analysis of Tape

Specimen lengths of tape are shown in Fig. 2, in which the events included in group *B* will be seen, with the modification that the working time of the tilters and manipulators has only been recorded when the table rollers are stationary. It can be assumed, therefore, that the working time recorded for these auxiliaries is that actually spent in turning the ingot. For the purpose of analysis, the holes in the tape are converted into electrical signals by means of a reader head (Fig. 3), and these signals are then interpreted by the analyser (Fig. 4). The tape is drawn through the reader by a sprocket wheel which engages with the feed holes in the tape. A motor-driven camshaft operates five peckers which press up under the tape and, as the camshaft rotates, it alternately releases and resets the peckers at the same rate at which perforations in the tape are stepped over them. If a pecker passes through a hole in the tape, a contact is closed and a counter in the analyser is operated for that particular circuit.

The analyser, in effect, counts the number of holes in each of the five tracks, the counting process for each track being automatically terminated when holes cease to appear in that track. The analyser can also group the number of holes counted into one of nine groups if required, the range of each group being set at a predetermined value. Information from the tape can therefore be reproduced automatically in a form suitable for a histogram. By appropriate connections to the contacts of the relays energized by the holes in any of the tracks in the tape, a desired character can be picked out. The speed of analysis is determined by the operating speed of the reader-head, which is fixed at 7 perforations per second.

Visual examination of the tapes is also possible and in some cases it may be more convenient to obtain information by direct observation and measurement rather than by using the reader-head and analyser.

Presentation of Results

Possible events to be recorded have already been

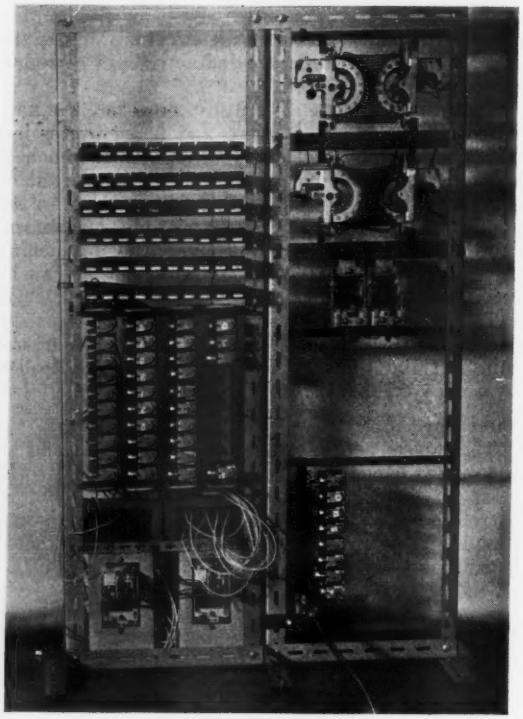


Fig. 4—B.I.S.R.A. punched tape analyser yielding histograms of recorded data

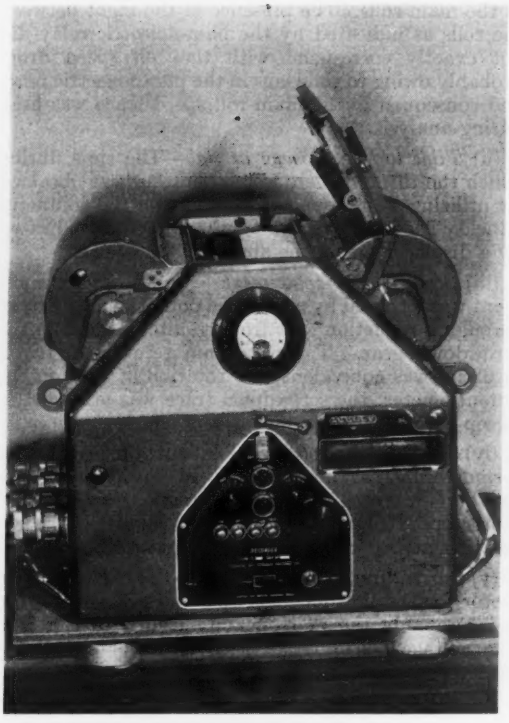


Fig. 5—Oscillograph recorder, yielding up to 12 continuous photographic traces

suggested, and from these, much information can be obtained regarding the time spent in and out of rolls. The times out of rolls with and without tilting, and with the ingot on edge or on the flat, can be compared, and the operating time of the screwdown can be examined with respect to the time available between passes. Information can also be obtained regarding the actual time taken for tilting-up or tilting-down.

The number of records to be taken will be determined by the objectives of an investigation, and factors peculiar to each installation will have to be considered; e.g. range of products rolled, operating methods, etc.

A detailed description of this work has been given in the companion paper in this issue.

12-CHANNEL RECORDER TECHNIQUE

Description of Apparatus

The 12-channel recording oscillograph is a commercial instrument, designed primarily for use in conjunction with strain gauge equipment, but this represents only one of its possible applications. Any event or variable which can be translated into a varying current can be equally well recorded. An illustration of the recorder is given in Fig. 5. The main feature of the instrument is a magnet block which holds 12 mirror galvanometers, insulated from one another. By means of a simple optical system, each galvanometer reflects a spot of light on to a moving photographic film, and also on to a glass screen, so that the traces can be watched during recording. The zero position of each spot is adjustable, so that the traces can be given any desired spacing. Timing lines are also photographed across the full width of the paper at the same time as the traces are being made; the time interval may be set at either $\frac{1}{10}$ s or $\frac{1}{100}$ s, the interval selected depending on the paper speed when recording.

A governed motor driving a series of rollers pulls the photographic paper from one loaded drum across the screen and into a take-up drum. By altering the gear train in the motor drive, a number of paper speeds can be obtained, i.e. 0·5, 1·0, 2·5, 5·0, 10·0, 25·0, 50·0 in./s. The paper used is 6 in. wide, and is obtainable in 200-ft lengths. A counter is provided on the front of the recorder, so that the amount of paper used can be determined at any moment. A second counter is installed inside the instrument which automatically moves on each time the stop button is pushed, and at the same time an image of the numbers

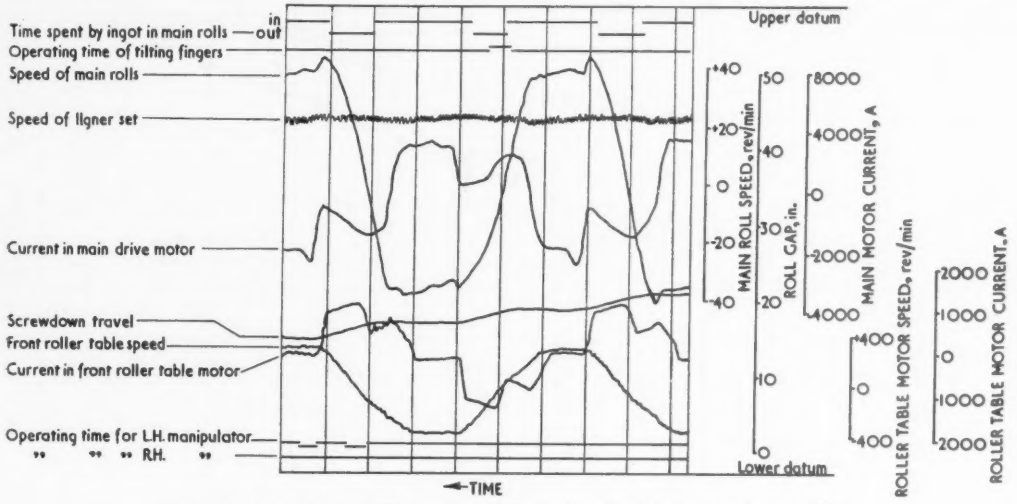
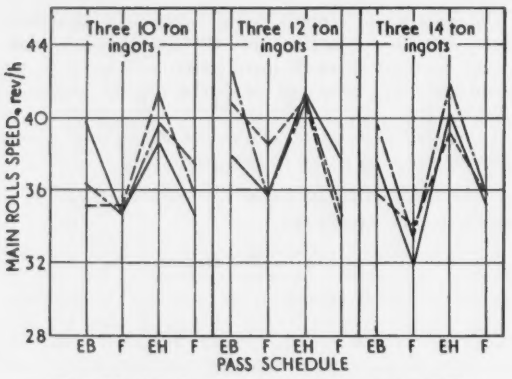


Fig. 6—Specimen chart record (vertical ordinates at 1 s intervals)



EB = Edge barrel pass (4), F_1 = Flat barrel passes (12),
EH = Edge hole pass (4), F_2 = Flat barrel passes (12)

Fig. 7—Main roll speeds, typical rolling sequence (14 tons)

is projected on to the paper. Each record is thus automatically numbered, and the record number can also be observed on a duplicate counter placed on the side of the instrument.

Another feature of the instrument is that any one of four lengths of paper between 0 and 10 ft can be run off automatically. When a switch is pressed, the recorder starts up and then shuts itself off when the selected length has passed through. The recorder can also be operated by remote control.

The instrument operates entirely on a 24-V d.c. supply, with a current consumption of between 10 and 11 A.

Operational Use

Methods used and items recorded during a short works trial carried out on a slabbing mill are shown below. A specimen chart record is shown in Fig. 6.

(i) *Ingot in main rolls*—A photo-electric relay was used in a similar way to that followed in the tape-perforator trials, to record the presence of the ingot in the main rolls. The presence of the ingot between the rolls as indicated by the photo-electric relay did not exactly correspond with the roll speed drop, probably owing to time lags in the photo-electric relay and consequently the main roll speed trace was used during analysis.

(ii) *Time to tilt an ingot or slab*—The time during which the tilting fingers were operating was obtained by utilizing a spare pair of contacts on the contactor panel. The operating time was therefore indicated by a displacement in the appropriate trace.

(iii) *Screwdown displacement*—Screwdown displacement was recorded by means of a potentiometer driven through a reduction gear from a suitable shaft in the screwdown gear. The maximum screwdown travel of 68 in. was equivalent to a rotation of 318° on the potentiometer: the screwdown trace was arranged to sweep across the full width of the paper.

(iv) *Speed of main rolls*—The existing tachogenerator for metering the main roll speed was replaced by another unit of known characteristic. For a main motor speed of 40 rev/min, the tachogenerator was rotating at 500 rev/min and producing about 12 V.

(v) *Current in main drive motor*—The current in the motor for the bottom main roll was measured, since it is probably the more heavily loaded of the two. The voltage across an existing ammeter shunt was used to energize the galvanometer unit.

(vi) *Current in front work roller table motor*—The current in the front work roller-table motor was also measured by using the voltage across an existing ammeter shunt to energize the galvanometer unit.

(vii) *Speed of front work roller table motor*—A tachogenerator was mounted on the base plate of the motor, with a 1 : 1 roller chain drive to a sprocket attached to the end of the motor shaft. For a motor speed of 400 rev/min the tachogenerator was producing about 10 V.

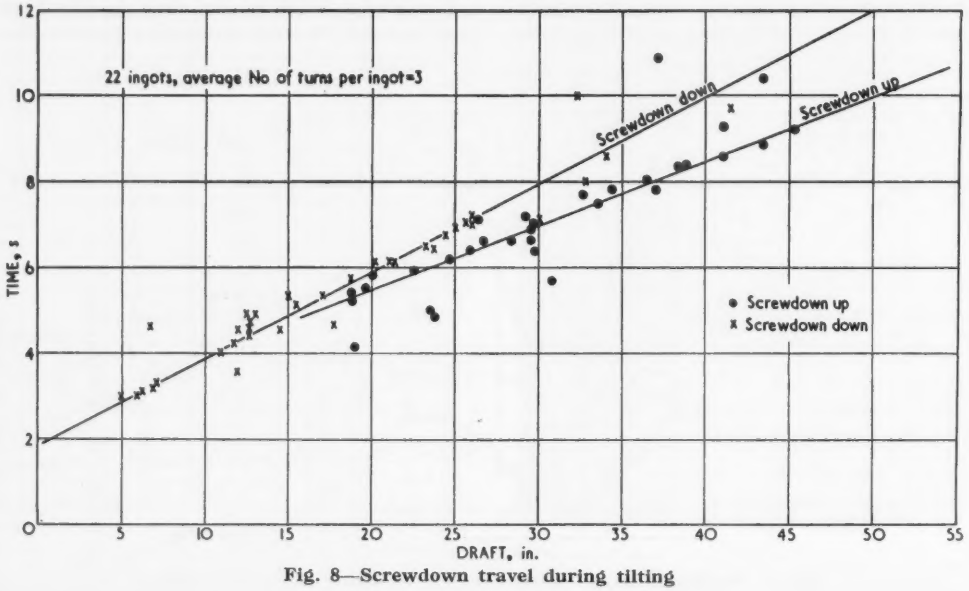


Fig. 8—Screwdown travel during tilting

(viii) *Speed of the Ilgner set*—The speed of the Ilgner set was measured by an existing tachogenerator belt driven off the main shaft of the set; the output was 50 V at 500 rev/min.

(ix), (x) *Operating time of the manipulators*—The operating times of the east and west manipulators were obtained by utilizing a spare pair of contacts on the contactor panel for each manipulator.

A 230-V a.c. supply was required for the photo-electric relay (i), while for items (ii), (iii), (ix), and (x), a 6-V Nife cell was used. The output voltage from each of the 10 items was fed into a multi-channel attenuator, so that the voltage could be limited to a suitable value for feeding into the recorder.

A few quick tests runs were carried out initially to determine the most suitable chart speed, and it was found that the slowest speed obtainable (i.e. 0·5 in./s) was adequate.

Accurate calibration of the various traces was carried out during short stops on the mill; the speed traces were calibrated by running the mill off load at a known constant speed for a few moments. For screwdown, the roll gap was set at given distances and records taken. Current calibration was obtained by connecting a voltage across the input to the appropriate attenuators equal to the rated voltage drop across the shunt while passing its full load current.

Analysis of Charts

From the records obtained during the works trial, the results of an analysis of a few features are included here to illustrate the type of data which can be obtained using the recorder as compared with that using the tape perforator. Detailed examination of the records would enable many other items of information to be obtained, such as the acceleration of the main roll and roller table, current surge in motors, etc.

(i) *Speed of main rolls*—Figure 7 shows the variation in speed of the main rolls for each series of passes in a pass schedule; three samples have been taken for each of three different ingot weights. For each pass series the rolling speed given is the average for the passes which occur in that series. The roll speed was faster during edge passes than flat passes and tended to be about 3 rev/min faster in the direction away from the pulpit. The reversal time for range 40–0–40 rev/min is quoted as 2 s; from the records examined it can be seen that a reversal time of 1·8 s for the range 40–0–43 rev/min was often achieved.

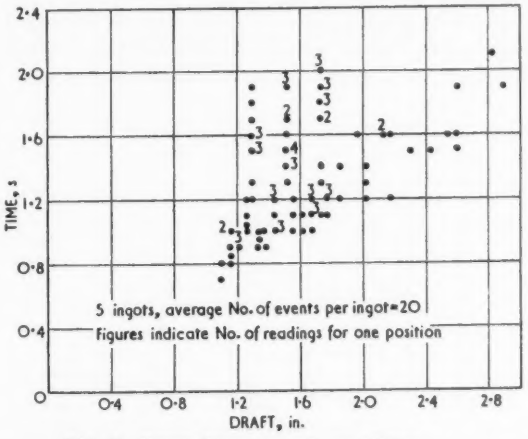


Fig. 9—Screwdown travel, no tilting

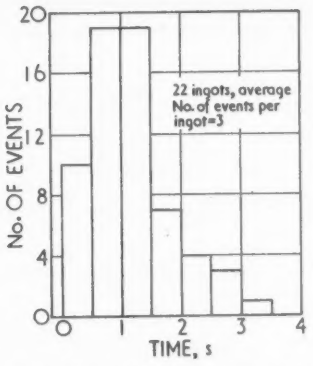


Fig. 10—Time interval between end of rolling and beginning of screwdown, with tilting

(ii) *Speed of front work roller table*—The normal maximum driving motor speed was 350 rev/min (i.e. table speed = 354 ft/min), with a reversal time of approximately 2·2 s for the range 350–0–350 rev/min. The table speed tended to be slightly faster inwards towards the main rolls than outwards; typical figures obtained were 357 ft/min inwards, and 353 ft/min outwards.

(iii) *Screwdown travel*—Figure 8 shows the times taken for the large screwdown adjustments which occur during tilting; 22 ingots, including 7 different weights, have been examined. The faster speed achieved when lifting the main roll can be attributed to the effect of the overbalance of the rolls.

With no tilting, the screwdown adjustment between passes is a few inches, and Fig. 9 shows the wide variation in the time taken; five ingots of one particular size (14 tons) have been considered.

During the alteration in the screwdown position when tilting occurs, the records show that the final setting was not always achieved the first time. For the 22 ingots already considered, during 70 operations overshoot occurred 20 times, 15 during screw-up and

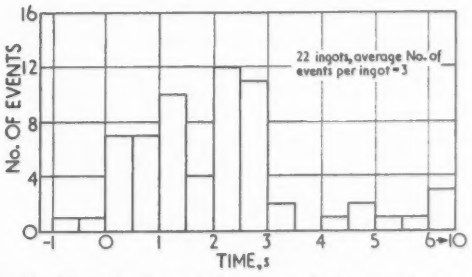


Fig. 11—Time interval between end of screwdown and beginning of rolling, with tilting

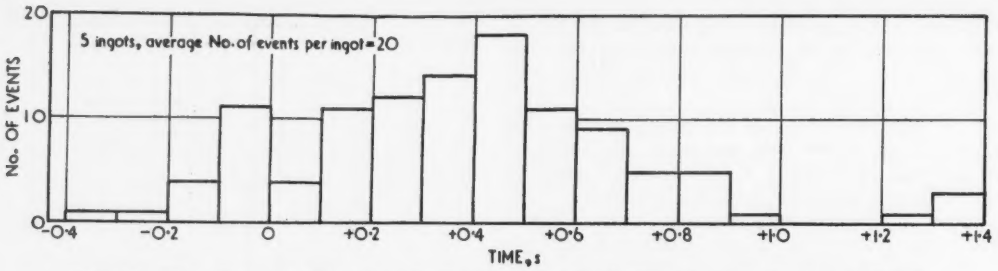


Fig. 12—Time interval between end of rolling and beginning of screwdown, no tilting

5 during screwdown. During screw-up the average overshoot was 1–1½ in., and during screwdown it was ½–1 in.

The records show no attempt at correction of these variations, presumably because there is no time spare between passes, as shown later. Although the schedule draft for these particular ingots was 2 in. for good heats, some variation down to 1½ in. would be expected with poor heats.

(iv) *Screwdown time in relation to the time out of rolls* —When tilting occurs, the time out of rolls is greater than the time taken for screwdown adjustment (Figs. 10, 11), but observation shows that on some occasions the ingot is waiting for the screwdown. Complete analysis of the roller table operations would show the cause of this delay.

With no tilting between passes, however, the time taken for the screwdown adjustment approaches very closely the time during which the ingot is out of the rolls. Figures 12 and 13 show that the screwdown may be expected to start moving about ½ s after the ingot has left the rolls, and to finish moving just under ½ s before it enters the rolls again.

DISCUSSION

The two instruments are complementary in their application. The tape perforator is useful for recording over protracted periods where statistical trends in performance are being looked for, because of its capacity for reducing large amounts of data automatically. The 12-channel recorder has the advantage of high speed of response and the ability to record directly variable quantities, which can be used for analysing the electrical and mechanical characteristics of a mill, including transient phenomena.

The tape perforator equipment and technique for recording data has been applied here to the study of primary mill operation, but its use is not limited to this type of mill, and there is no reason why it should not be well applied to the study of other types of machinery.

The tape perforator used as described here records events but not variable quantities. Such quantities could be recorded if necessary, but the amount of equipment required would be increased, and the simplicity of the equipment in its present form would be lost. In cases where detailed investigations involving these measurements are required, the 12-channel recorder is probably more suitable.

The use of the 12-channel recorder for works investigations does not raise any great difficulties in setting up or in recording, but particular attention must be paid to the arrangement of the traces on the charts, particularly when several are crossing over each other. Time spent on careful arrangement of the positions of the traces is more than repaid by the ease and certainty with which subsequent analysis can be carried out. Analysis of the traces, however, can be carried out only by observation and direct measurement. It is advisable that in cases where this recorder is used, the number of records should be limited to the minimum, otherwise considerable time will be required for analysis.

Where events and quantities have to be recorded together, then the combined use of both instruments might be considered, putting events on the tapes and quantities on the chart. It would be desirable to have the paper speed the same for each instrument in this case, so that the tape and chart may be compared side by side if necessary. As an additional precaution,

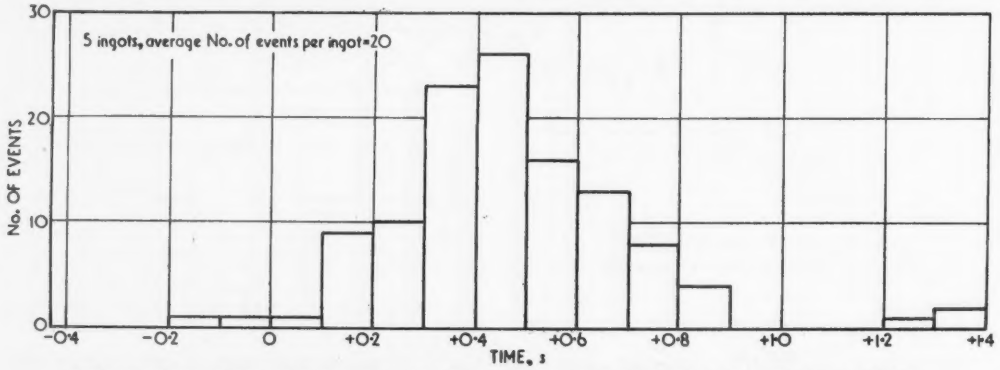


Fig. 13—Time interval between end of screwdown and beginning of rolling, no tilting

some form of signal might be duplicated on each paper to ensure that they can be synchronized.

FURTHER DEVELOPMENTS

When using the tape perforator system, if the record of each ingot is numbered it is considerably easier to identify any particular ingot during analysis. A number marker is therefore being developed which has a range 0–100, and by which any required number can be represented in code by a character; i.e. a combination of holes and spaces on the tape. The marker can be pre-set, the actual perforation taking place at the time required by operating a push-button control. By perforating the record number at the appropriate time, it can also be used to indicate the time of arrival of a fresh ingot at the mill.

Since with one tape perforator five channels only are available for recording events, the choice of what events to record requires some care. Where certain events cannot happen together, however, it is possible by means of a suitable code to record more than five on one tape. It is hoped to carry out some tests in the future on the possibility of using more than one tape perforator in parallel; one event will probably have to be duplicated on each tape, however, for synchronization purposes.

Acknowledgments

The authors wish to acknowledge the co-operation and assistance given by the Operational Research Department, the Electrical Engineering Department, and the Hot Mill Production Staff of the Steel Company of Wales, Ltd., Abbey Works, during the development of these techniques at the works.

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The Time Characteristics of the Slabbing Mill

By H. G. Jones, D. T. Steer, and P. D. Dickerson

SYNOPSIS

The object of breaking down the rolling process into functional components is to enable the time to be synthesized for the rolling of any ingot to any slab section.

Numerical values of the constant and variable time components of the rolling of a slab are quoted and their importance discussed. The synthesis of the components is illustrated for a particular case and the general validity of the synthesis is checked by reference to a detailed study of three shifts.

The effects of the speed of the work rolls of the mill and of deeper draughting on the output of the mill are also discussed. 1215

IN AN INTEGRATED iron and steelworks, the outputs from several individual items of plant converge into a single stream to pass through the slabbing mill. This single unit can thus be the factor determining the tempo of the whole plant so it is clearly desirable to establish a firm figure for its ultimate capacity. The logical procedure when the unit is of heavy capital cost is to saturate this unit to its working capacity by multiplying the streams feeding it.

The fluctuations to be expected from hour to hour are also of importance, both when considering the equipment to be associated with the mill and also if productivity indices are to be established.

As a first stage, the time characteristics of the slabbing process itself will be established. Later, it is proposed to extend the study to embrace some aspects of the optimum designs of ingots and finally to indicate some of the factors controlling the slabbing capacity.

The numerical values quoted in this paper refer to the high-lift reversing slabbing mill, of the Abbey Works, which has been adequately described elsewhere.[1]

CHOICE OF COMPONENTS

In any time study, an early review of the various ways in which the operation could be broken down into component parts is essential, both to reduce the amount of observation to a minimum and to ensure the synthesis of times of operations possibly not in progress during the period of observation.

In studies of the primary mill, B.I.S.R.A.[2] initially used a breakdown into the total number of passes required to reduce an ingot to a slab. This method of analysis implied, for all ingots, the same pattern of rolling in the number and sequence of tilts. Moreover, this breakdown does not yield a simple method for estimating the rolling rates of ingots of other sizes and shapes.

From the analysis of shift outputs, Gobiet and Schnick[3] have estimated the times to roll a number of different ingots in order to develop a bonus scheme related to the amount of work required from the rollerman. Bleimann,[4] using direct observations, estimated the total time to roll an ingot, and, by the use of an ingenious timing device to obtain sufficient data, compensated for plant delays superimposed on the rolling pattern. Although recognizing the influence of the rolling sequence, the work both of Gobiet and Schnick and of Bleimann was based on

Manuscript received 5th September, 1955.
The authors are with the Operational Research Section of The Steel Company of Wales Ltd.

Table I

MEAN TIMES OF INDIVIDUAL COMPONENTS FOR THE ABBEY SLABBING MILL RUNNING AT 40 rev/min

	Single Ingots		Tandem Ingots	
	Time, s	2 Standard Errors, s	Time, s	2 Standard Errors, s
Time in contact with rolls for one pass	0·0106 × (length in inches) + 0·28	0·02	0·0126 × (length in inches) + 0·60	0·04
Time out of rolls without tilting:				
Between flat passes	2·12	0·03	2·16	0·04
Between edge barrel passes	2·29	0·08	2·15	0·09
Between edge hole passes	2·60	0·08	2·43	0·14
Time out of rolls with downtilt	9·2	0·3	8·7	0·3
Time out of rolls with uptilt	10·4	0·4	11·0	0·6
Time from end of ingot to beginning of next	0·125 × (length of screwup in inches) + 8·1		0·125 × (length of screwup in inches) + 8·1	
Time from end of tandem to beginning of first single of pair			11·8	0·8
Time from end of first single to beginning of second single of tandem pair			16·7	0·5

the total time to roll an ingot, thus making it difficult to transfer the results to conditions different from those examined and moreover failing to indicate the directions from which improvement might come in the actual rolling process.

Certain factors, e.g. the time the ingot is in contact with the rolls, are some function of the length of the ingot at each phase of its reduction to a slab. Superficially, it also appears that other factors, for example, time out of rolls or time of tilt, might be substantially independent of the length of ingot or slab. Pioneer studies carried out in 1951 by Whitehouse and Lee[5] with stopwatches indicated the validity of this approach, within the limits of accuracy imposed by the measuring techniques then available.

Stopwatch investigations carried out early in 1954 by the Royal Netherlands Blast Furnaces and Steelworks[6] lead to similar breakdowns of fixed components and a time in contact with the rolls which was, for most of the lengths rolled, a linear function; for short lengths, the Dutch workers found times greater than would have been expected, i.e. the time/length curve had an upward trend at its lower end, because the ingot was not fed in at full roll speed.

The idea of feeding the response from a photocell, directed between the windows of the millstand, to a millivolt high-speed recorder for the purpose of measuring the time in contact with the rolls was explored with the Abbey Electrical Engineering Dept. in the early spring of 1954. The cell used was a standard Mazda PE7B photocell with a caesium–oxygen–silver cathode (sensitive to red and infra-red radiation), for which the makers claim a response time of 1/25th of a second. However, if the degree of contrast between the signal and the background is not sharp enough, the B.T.H. photoelectric relay (type *G*, form *S*) used in the circuit might, according to the makers, be as much as 1/10th of a second late in dropping out of circuit after an ingot has passed.

The use of the cell is not beyond criticism in that during edge passes, a fishtail in the slab might cause the cell not to pick up a signal for a short time when rolling work was taking place; conversely, if the slab is reduced in its end section, the cell can quite correctly pick up a signal before (or after) working contact with the rolls occurs. In spite of these disadvantages, observations with the photocell are more accurate than can be obtained with a stopwatch and are less liable to errors in interpretation than the high-speed charts (6 in./min) of mill speed or mill current which were examined at the same time.

When the B.I.S.R.A. teleprinter equipment[7] was developed, it appeared opportune to carry out a more elaborate investigation both with more accurate timings and with more extensive data than was hitherto possible. The teleprinter tape has five channels for the reception of signals in addition to the time base. For the first tests, the channels were used to record

(*a*) time in rolls
(*b*) screwup time
(*c*) screwdown time
(*d*) manipulation time
(*e*) time finger lifts operated.

The photocell gave the signal for the time in contact with the rolls: the other signals were obtained from appropriate connections to the control circuits of the mill electrical equipment.

In recording screw motions, a continuous signal giving the position at any instant would be ideal: at the time of the tests, suitable equipment was not available, so the time the screwdown was in motion was recorded. Since it was desired to know whether

'hunting' took place in setting the screwdown, two channels were devoted to the times of screw movements. (No evidence of 'hunting' was found in the present trials.)

The Abbey Electrical Engineering Dept. arranged (by interlocking) that the teleprinter received signals from the manipulators and tilting fingers only when the table rollers were stationary, and therefore presumably when the ingot was actually being tilted. It is, of course, within this period that the use of the manipulators and fingers is the controlling factor on the mill performance.

It would also have been of interest to have recorded separately the reversal times of both the mill rolls and the table rollers, but channels on the teleprinter tape were not available. The times of these reversals are reflected in the time out of rolls component obtained by difference from the time in rolls record on the teleprinter tape; but in the Abbey mill it is not yet certain whether the reversal time or the speed of screwdown governs the time out of rolls.

It was also essential when a range of slabs was being rolled to have at least one observer in the pulpit to record the size of ingot, the draughting, and the rolling pattern by which the ingot was reduced to a slab. The observers also noted the cause of small delays such as failure of the slab to enter the rolls.

ANALYSIS OF ROLLING COMPONENTS

The bulk of the data for the analysis was obtained during 48 hours' intensive observation in June, 1954. This short intensive period was selected partly for administrative reasons and partly because steel was coming forward at a rate steady enough to ensure that the rollermen settled down to their normal pattern of work. Moreover, the sample contained approximately equal numbers and types of ingots rolled by the three rollermen or their reliefs. No significant differences between rollermen were found as far as component times were concerned.

Records were obtained for about 400 ingots described by the mill operators as being of satisfactory heat. The pulpit observations for a few of the ingots could not be completely co-ordinated with the tape records so these ingots were discarded from the analysis. From the remainder, estimates were

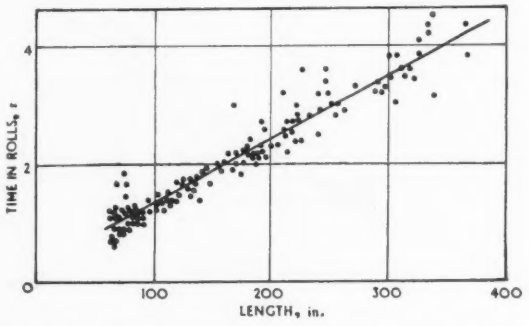


Fig. 1—Time in contact with roll versus length of ingot or slab for single ingots

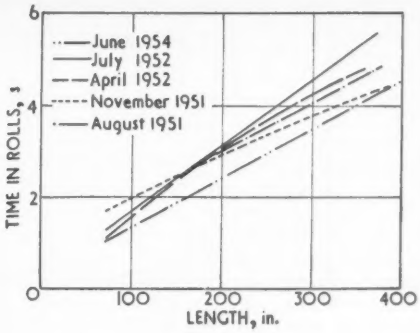


Fig. 2—Derived curves for single ingots

obtained of the component times shown in Table I and are discussed in detail below.

Time in Contact with Rolls

The length of the slab was estimated at each pass from the density (assumed to be 0·283 lb/in³), the weight of the ingot (obtained from a weighbridge situated in the roller table feeding the slabbing mill), and the area of cross-section.

It was assumed that the vertical dimension of the slab emerging from the mill was identical with the distance between the work rolls as measured by the roll setting. In estimating the width of the slab at each pass, one can either

(*a*) assume the width is the same as for the previous pass on the width or

(*b*) compensate for the spread during rolling by arbitrary increments so as to obtain the known width for the next pass on the width.

By using (*a*), the length of the slab will be overestimated by at least 3% and moreover the error will increase during each set of passes. The other method has the double merit of representing the rolling process more closely as well as reducing the 'scatter' in the observations and has therefore been adopted in this work.

The results for the time in contact with the rolls are shown in Fig. 1 for a 5% sample of the total observations selected by random number tables; the straight line is that estimated for all ingots by the method of least squares, and is represented by

$$\text{(Time in seconds)} = 0{\cdot}0106 \times \text{(length in inches)} + 0{\cdot}279 \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

It is noteworthy that the observations included a range of ingots from 7 tons to 16 tons being rolled to a wide variety of final slab sections; the curve giving the best fit was a straight line. In investigations from 1951 to 1954, various other linear and non-linear curves, shown on Fig. 2, have been fitted to the observations. It is not certain how far the differences between these curves represent improved rolling practice acquired through experience or how far the differences can be attributed to experimental errors.

When rolling consecutive ingots to identical slabs, it is frequently the practice to roll two ingots, pass by pass, one behind the other. The object is to save time out of rolls occupied with screwdown and

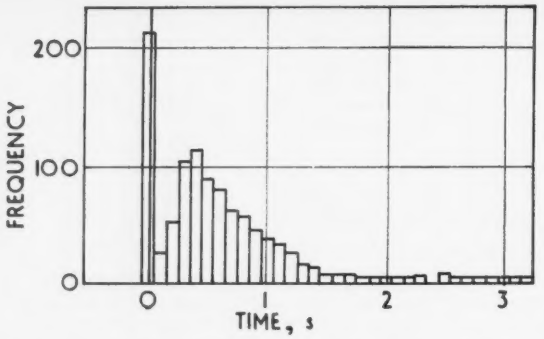


Fig. 3—Interval between exit of first ingot and entry of second ingot when rolling in tandem

manipulation by performing these operations once only for a pair of ingots. Such a practice is described as ' tandem rolling '. Should the ingots be part-rolled in tandem and then for some reason (such as becoming too long for both to be handled by the manipulators for instance) receive the later passes as single ingots, the process is known as ' semi-tandem rolling '.

The teleprinter observations for tandem rolling have been analysed in two distinct ways. In the first, each ingot of a pair has been treated as a single ingot with the time between the ingots regarded as a separate component. The time/length relationship was found to be identical with that of Fig. 1 for single ingots. The distribution of the times between tandem ingots on Fig. 3 is of some interest; after the first sharp fall in the histogram at 0·1 to 0·3 s, there is a negative exponential distribution of times: the longer times appear to be associated in general with the longer slabs. In a few cases, the time between ingots is too small to be registered on the teleprinter: this apparent failure of the recording system caused some concern even though zero times will be expected from the teleprinter characteristics on half the occasions if the time lies between 0 and 0·1 s. Extensive visual and stopwatch observations, however, have confirmed that the distribution of Fig. 3 is substantially correct. If, on the other hand, the time out of rolls between each pass had been underestimated by as much as 0·5 s, the time in rolls would of necessity have been over-estimated by the 0·5 s. The net effect on the total time to roll the ingot would then be an over-estimate of 0·5 s (or not more than 1·0%) due to the last pass.

The alternative method of analysing tandem rolling is to treat the pair as a ' single ' slab with the interval between the slabs regarded as part of the ' single ' slab. Figure 4 illustrates the results obtained for a 10% sample selected by random number tables. The curve of best fit for all the results is again a straight line, given by

$$\text{(Time in seconds)} = 0{\cdot}0126 \times \text{(length in inches)} + 0{\cdot}601 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Time Out of Rolls, not Tilting

Time out of rolls without tilting is one of the most frequent components. Because of its importance, the analysis has been broken down into three phases, namely

(*a*) time out of rolls between flat passes, single or tandem ingots
(*b*) time out of rolls between edge barrel passes, single or tandem ingots,
(*c*) time out of rolls between edge hole passes, single or tandem ingots.

It was first verified that within the 7–16 ton range of ingots examined, there was no correlation between the weight of the ingot and the time out of rolls. Histograms of the various times are therefore shown on Fig. 5 for all ingots. Although the positions of the peak frequencies are not greatly dissimilar, the longer tails associated with the edge hole passes yield greater mean times for this component (Table I); the longer times seem to be due to the greater care necessitated from the operator in registering the slab during edge hole passes.

Time Out of Rolls, with Tilting

Again it was first verified that the times for both uptilt and downtilt were independent of the weight and the length of the slab within the range examined. The distributions obtained are shown in Figs. 6 and 7. The mean times for downtilt are somewhat smaller than uptilt (Table I).

Histograms have also been drawn (Fig. 8) for the times of operating the finger lift when the table rollers were stationary. In each case, a secondary peak is present, particularly in the flat to edge tilts. A significant correlation is obtained between the total time out of rolls during tilt and the time of tilt which agrees with the hypothesis that the subsidiary peaks correspond to second (or even third with tandem ingots) attempts to tilt the slab. The effect of these second attempts to tilt the slab is to increase the mean time out of rolls during tilting by about 0·5 s for single ingots; no reliable estimate for the increase with tandem ingots can be given at this stage.

During this work, cinematograph observations taken by Chard of B.I.S.R.A. have confirmed that two distinct types of tilting action occurred with all the rollermen. In the one, a continuous sweeping lift as far as required could be seen during the relatively

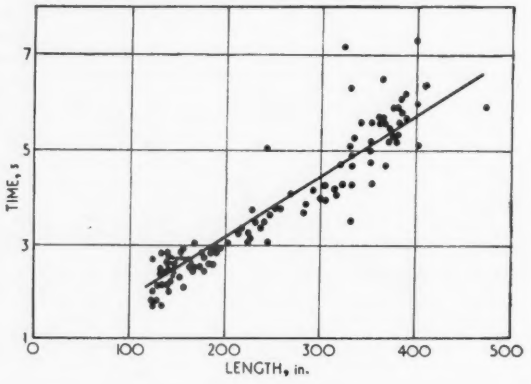


Fig. 4—Time versus length, including interval between ingots for tandem ingots

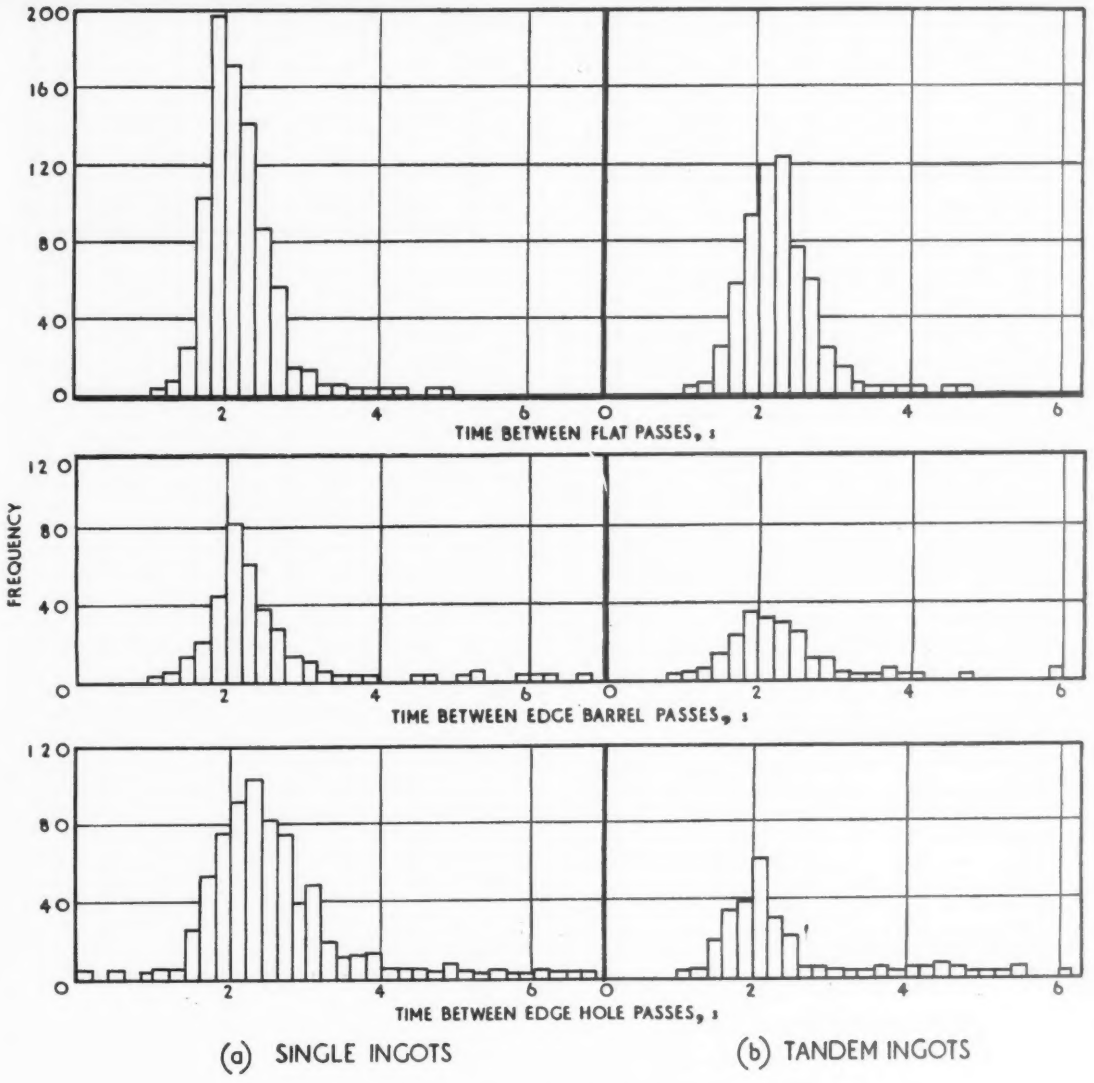


Fig. 5—Distribution of time out of rolls, not tilting

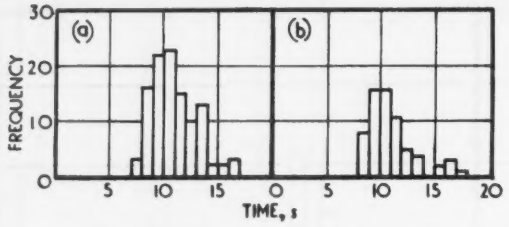
slow projection of the film; alternatively, and especially on the uptilt with a thin section, the slab might be lifted a part of the way, rested against the manipulator, and the lift finally completed. There appeared to be no major difference in the times arising from the different techniques.

Time from End of Ingot to Beginning of Next Ingot

When the mill is working under peak conditions, the theoretical time between ingots should merely be that necessary to adjust the roll (by the screwdown) to its new position. Time measurements from teleprinter tapes have given the results shown on Fig. 9, on which the straight line corresponds to the nominal speed of 40 ft/min. There is no marked increase in the spread of the observed readings as the roll reaches its upper position, as might be expected if the rollermen were over-cautious. For all positions, acceleration and retardation jointly appear to require about 2 s, the equation of the line being

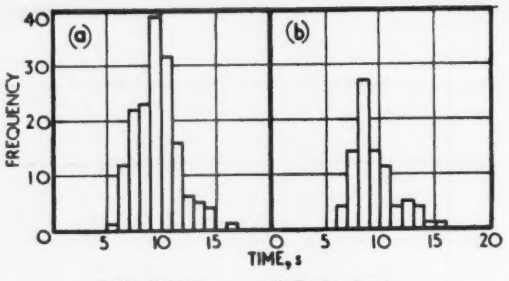
$$\text{(Time in seconds)} = 0{\cdot}125\ \text{(length of screwup in inches)} + 2{\cdot}1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Exhaustive observations on three peak and other shifts have indicated that in addition to the theoretical time resetting the mill, there occurs an operational delay, on average amounting to 6 s, necessary to align



(*a*) Single ingots (*b*) Tandem ingots

Fig. 6—Time out of rolls, uptilt



(*a*) Single ingots (*b*) Tandem ingots

Fig. 7—Time out of rolls, downtilt

the new ingot to the millstand. The final time between ingots is therefore given by

(Time between ingots in seconds) =
0·125 (length of screwup in inches) + 8 .....(4)

Time from End of Tandem to Beginning of Semi-tandem

Suitable ingots are rolled in tandem, but when their joint length would become either too great for the manipulators or too great for the roller table, it is essential to stop the tandem process and finish the slabs separately. The second slab has to be safely located at the end of the roller table before rolling on the first slab can recommence. This parking process consumes operating time, the distribution of which is shown on Fig. 10.

Time between Semi-tandem Ingots

When the rolling of the first semi-tandem slab is completed, a further operation is required to bring up the second slab and to reset the mill. The distribution of the times for this component is shown on Fig. 11 to be more compact than during the parking operation about a time, 4 s longer than for the parking. The increase in time occurs because the second slab cannot be advanced between the manipulators until the first slab has left the manipulators on the side remote from the pulpit.

TIME TO ROLL AN INGOT

The object of breaking down the rolling process into logical or functional components is to enable the time to be synthesized for the rolling of any ingot to any slab section. Thus, if a nominal 15-ton ingot of mean cross-section 51½ in. × 36¼ in. is to be rolled to a slab of final section 31 in. × 8½ in., the first pass will be on the barrel with the screwdown set for 50 in.; this would be followed by five passes on the ' edge ' of the ingot each with a draughting of 2 in. The ingot would next be downtilted. The first pass on the ' flat ' side of the ingot would be with the screwdown at 36 in.: this would be followed by five passes on the ' flat ' side of the ingot each with 2 in. draughting. The complete rolling of the ingot would be determined by the following screwdown settings:

Edge barrel	50	48	46	44	42	40		
Flat	36	34	32	30	28	26		
Edge barrel	40	39	38	36				
Flat	26	24	22	20	18	16	14	11½
Edge 14-in. hole	38	35	32	29½				
Flat	11½	10	8½					

The passes between each tilt are known as a ' set of passes ' so that the rolling sequence above would be described as comprising ' six sets of passes '. The rolling sequence consists of a total of 31 passes containing 3 downtilts, 2 uptilts, and 25 intervals of time out of rolls without tilting; the total times for these can readily be obtained from Table I.

The estimated length after each pass is shown on Fig. 12. The full line shows the length obtained by arbitrarily correcting for the Poissonian spread in width during rolling. If the width were taken as that of the previous screwdown setting for the width, the calculated lengths would be as shown by the broken line on Fig. 12; for this ingot, the total length rolled would be over-estimated in this way by 3·4% giving an over-estimate in the total time to roll the ingot of 1·9 s or 1·1%. If, on the other hand, the mean length were multiplied by the number of passes, the total length rolled would be over-estimated by as much as 35%.

The total time to roll the 15-ton ingot to this particular slab is estimated to be 171 s, made up as follows:

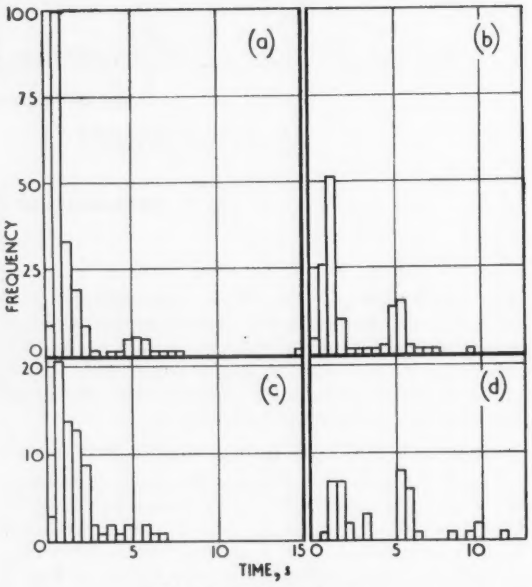


Fig. 8—Tilting times

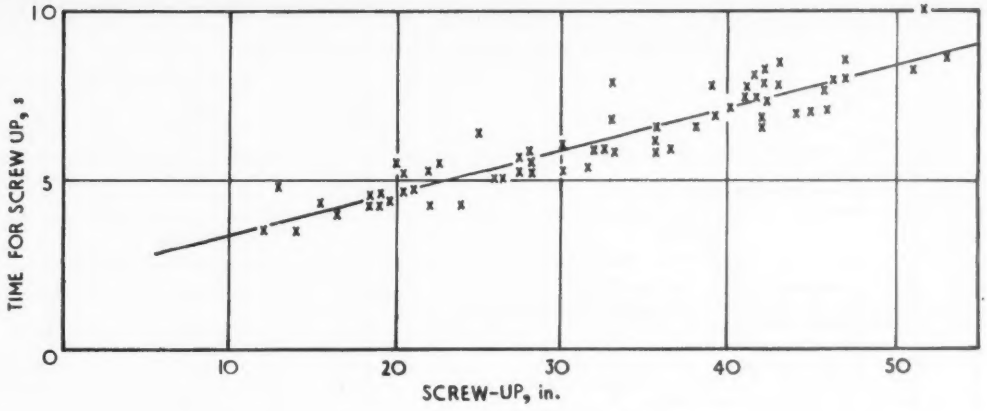


Fig. 9—Time of screw-up

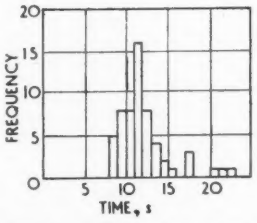


Fig. 10—Time from end of tandem to beginning of first ingot of semi-tandem

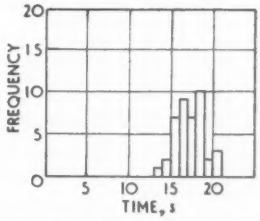


Fig. 11—Time from end of first single to beginning of second single of a semi-tandem pair

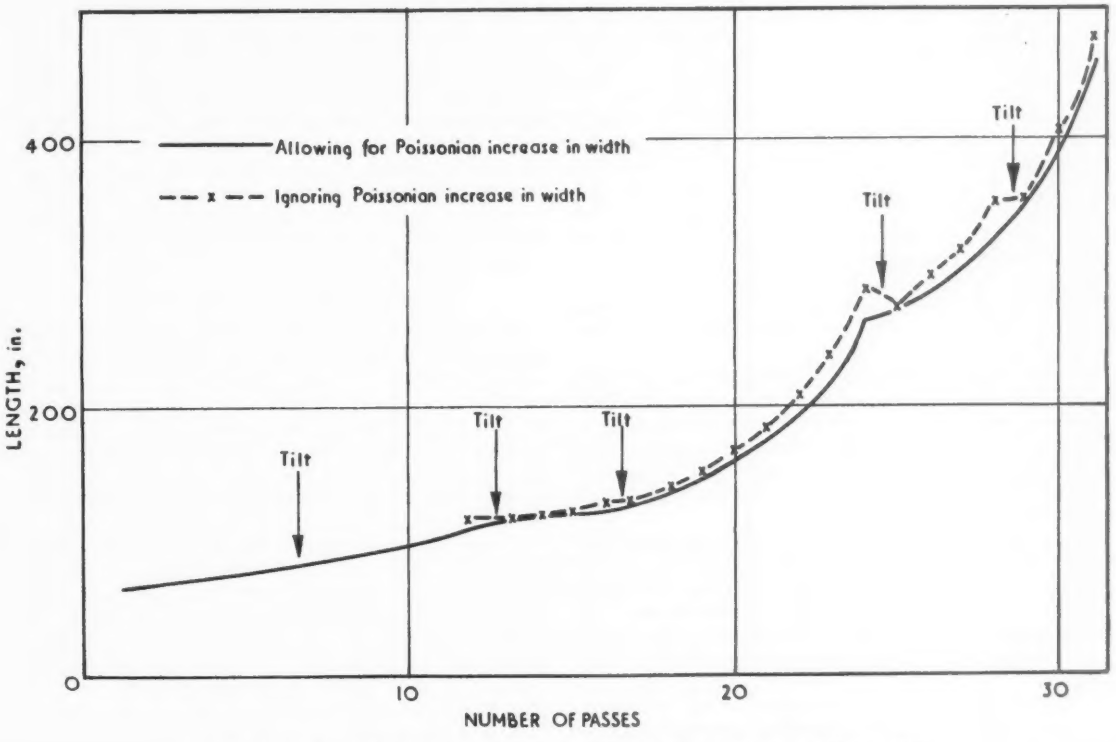


Fig. 12—Calculated lengths of 15-ton ingot rolling to 31 in. × 8½ in. slab

Table II

SUMMARY OF INDIVIDUAL SHIFT WORKING

		Sunday 6.2.55 6–2 shift	Sunday 20.2.55 6–2 shift	Sunday 27.2.55 6–2 shift
	Tonnage rolled	2561	2311	2235
	Total item of observations, min	468·7	473·0	451·0
Item No.	Element	Time, min		
1	Total predicted time to roll tonnage	393·7	404·4	369·5
2	Time for extra passes through mill stand due to indifferent heat, etc.	35·6	46·5	34·9
3	Turning ingots over	5·2	0·2	—
4	Returning previous slab for squaring	2·8	—	0·9
5	Rolling delayed by ingot on weighbridge	0·5	—	0·5
6	Delay at shears stops rolling	—	0·5	—
7	Delay at edger stops rolling	—	—	32·6
8	Motor room delay	2·2	—	3·2
9	Adjusting draughting dial in mill pulpit	6·0	—	—
10	Cover crane broken down delays ingot delivery	—	—	4·6
11	Removing scrap from rolls	—	26·6	—
12	Repairing water pipe on mill stand	14·0	—	—
13	Time unaccounted for, i.e. error of the prediction	+ 8·7	− 5·2	+ 4·8
14	Total delays to rolling, i.e. items 5–12	22·7	27·1	40·9
15	Time which could have been saved by rolling in tandem if mill could have been supplied quickly enough with steel	15·2	14·1	17·8

Total time in contact with rolls	= 65·4	seconds
25 intervals with no tilting	= 55·4	,,
3 downtilts	= 27·6	,,
2 uptilts	= 20·8	,,
Nip on last pass	= 2·0	,,
	171·2	,,

On roughly one-half of the occasions, it is the practice to nip the leading edge of the ingot for a period, on average, of 4 s (to minimize any tendency for the fishtail to open in subsequent processing); for convenience in the calculations this is taken as being equivalent to 2 s on the last pass of all ingots. After allowing for the time between ingots and for the actual weight of the ingot being 15·4 tons, the peak rolling rate to be expected under these conditions would be 300 tons/h.

If this ingot were rolled in tandem for the first four sets of passes and finished in semi-tandem, the total time to roll the 30·8 tons of steel would be 290 s, corresponding to a rolling rate of 366 tons/h (after allowing for the time between ingots); that is, tandem rolling enables the mill to process 66 more tons of steel per hour with this ingot.

A point of interest is the shallow draughting (about 6 in. in 4 passes) shown for the second set of edge passes. This could clearly have been done in 3 passes but in order to reach the tilting device the ingot would then require to be passed through the mill with no work being done—such a pass is known as a ' dummy pass '.

Should the quality requirements permit the rolling of this ingot in four sets of passes, thereby enabling both a downtilt and an uptilt to be eliminated, the saving in time would amount to 15 s per ingot or to an increased throughput of 28 tons/h with single ingots.

It is of some interest to note that useful work on the ingot (i.e. time in contact with the rolls) only occurs for 35% of the process. The single most time-consuming operation is tilting and its associated operations. A universal mill, with a set of vertical rolls just in front of the horizontal rolls, could be installed to reduce the number of tilts, and also, by stopping the spread on the vertical sides of the ingot, would save about 2 passes per ingot. With this slab, it is estimated that a universal mill would reduce the rolling time by at least 11%.

VERIFICATION OF PREDICTION

Having developed a method of predicting outputs, it is essential to ascertain by observation the accuracy of the prediction. Since a plentiful supply of steel is usually available at the mill on the 6.0 a.m.–2.0 p.m. shift on Sunday mornings, it was decided to study in detail the rolling operation of three such shifts. It was also believed that these shifts would correspond most closely to the conditions to be expected in the future.

Using the teleprinter equipment on loan from B.I.S.R.A. at a speed of two holes per second, the overall time to roll each individual ingot and more particularly the length of delays were recorded. In addition an observer noted the details of draughting, the number of passes, and other relevant information.

The first step in the verification was to calculate the time taken to roll each individual ingot or pair of ingots to the specified slab size; this was accomplished by using the basic times and formulæ described above.

Table III

MEAN TIMES OF INDIVIDUAL COMPONENTS WITH VARIOUS ROLL SPEEDS

Component	Roll speed						
	20–30 rev/min	40 rev/min		50 rev/min		60 rev/min	
	Tandem	Single	Tandem	Single	Tandem	Single	Tandem
	Time, s	Time, s	Time, s	Time, s	Time, s	Time, s	Time, s
Time in contact with rolls	0·022 × (length in inches) + 1·29	0·0106 × (length in inches) + 0·28	0·1216 × (length in inches) + 0·6	0·008 × (length in inches) + 0·73	0·008 × (length in inches) + 1·32	0·007 × (length in inches) + 0·96	0·008 × (length in inches) + 1·02
Time out of rolls without tilting:							
Between flat passes before the 14in. hole*	1·8	2·1	2·2	1·9	2·0	1·8	2·4
Between flat passes after the 14in. hole*				2·9	3·1	3·1	3·0
Between edge barrel passes	2·0	2·3	2·2	2·2	2·1	2·2	2·3
Between edge hole passes	2·0	2·6	2·4	2·0	2·1	2·2	2·3
Time out of rolls with downtilt	7·8	9·2	8·7	8·3	7·9	7·6	8·6
Time out of rolls with uptilt	9·7	10·4	11·0	9·4	9·8	9·1	9·8
Time from end of tandem to beginning of first single in semi-tandem	9·8		11·8		12·6		11·0
Time from end of first single to beginning of second single in semi-tandem	17·4		16·7		14·5		12·9

* These differences are due to the operator taking longer to adjust the screwdown for the last passes, when fine adjustment of the screwdown is important. The differences were not obtained during the 20–30 and 40 rev/min trials, in the case of the 20–30 rev min trial owing to lack of data, and in the case of the 40 rev/min trial, to the failure of the photocell mechanism to record all final flat passes

The sum of these individual calculations represents the theoretical time to roll the shift tonnage and is shown as item 1 in Table II. It should be mentioned that none of the shifts was particularly suitable for achieving record shift tonnages because of the number of sections with relatively low rolling rates.

The calculation of the time to roll individual ingots obviously depends on the number of passes which have been applied to reduce it to the correct slab size. The theoretical draughting used was 2 in.

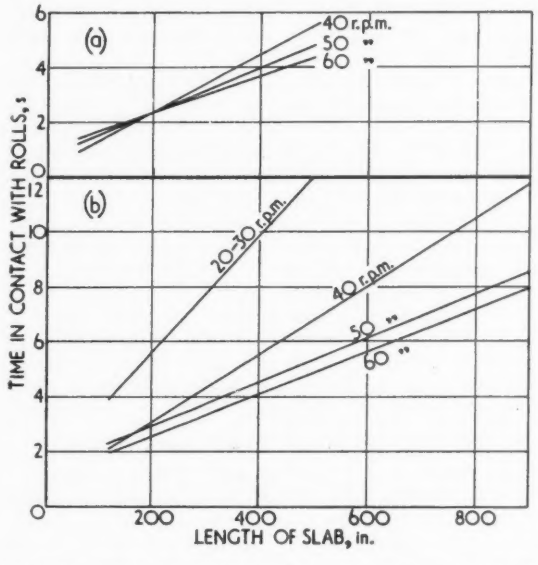


Fig. 13—Time in contact with rolls versus length of slab for different speeds but constant draughting: (*a*) single ingots; (*b*) tandem ingots

(apart from the conditions when dummy passes would be otherwise necessary to get the slab on the right side of the mill for tilting); similarly, there was an agreed division of ingots into those which can be rolled in four sets of passes and those requiring six sets of passes.

Observation of the number of passes actually used showed that at times there was a tendency to make more passes than the theoretical minimum. The extra passes may be attributed to the following causes:

(*a*) Some slabs were passed through the 9½-in. edging hole to meet special strip mill requirements with regard to quality.

(*b*) Soaking pit performance was not constant; refractory repairs and minor adjustments to combustion conditions may be called for from time to time. These factors occasionally result in some pits producing ingots which are sometimes rather colder than is desirable for good rolling practice.

(*c*) At times a few ingots have a cold side due to bad charging arrangements as a result of mis-shapen ingots, bad bottoms, or fins and when this happens ingots tend to camber during rolling: it is then necessary to turn the ingot over during rolling and also to use a greater number of passes. Item 3 shows the time actually taken in turning ingots over.

(*d*) Individual operators tend to use slightly different techniques.

Very occasionally it was also found that a smaller number of passes had been used than the theoretical minimum.

The extra time required for the extra passes has been estimated and is shown as item 2 in Table II. This amounts to approximately 10% of the predicted time to roll and should normally be included in any future estimates of the output of the mill. The remainder of the items in the table are delays of one kind or another and in most instances are self-explanatory. It appears from item 14 that the minor

Table IV

INFLUENCE OF MILL SPEED ON THE TIME TO ROLL SELECTED INGOTS

Roll speed		20 rev/min		40 rev/min		50 rev/min		60 rev/min		
Ingot nominal weight, tons	Slab section, in.	Time to roll ingot, s	Rolling rate, tons/h	Time to roll ingot, s	Rolling rate, tons/h	Time to roll ingot, s	Rolling rate, tons/h	Time to roll ingot, s	Rolling rate, tons/h	Method of rolling
7	31 × 6	239	247	176	335	161	367	159	371	Tandem
10	39 × 8½	201	383	151	510	140	550	139	554	Tandem
12	50 × 8	201	460	152	609	141	656	140	661	Tandem
15	31 × 8½	—	—	303	391	278	427	272	436	Semi-tandem
18·6	70 × 5	—	—	126	531	123	544	122	549	Single

delays to the mill would be of the order of 5–10% as a first rough estimate.

Observations have also been carried out on several other shifts in an attempt to give generality to the minor delays to be expected on the mill. The present tonnages, although they are large by comparison with many mills, are—owing to limitations imposed by the capacities of the melting shops supplying the steel—so far below the theoretically estimated capacity of the mill, that the observations, when translated into the future, can carry no greater weight than the very rough figures of 5–10% quoted for the three shifts.

It was also observed that because the present buggy cycle serving the mill with steel is too long to cope with extremely high rolling rates, a considerable number of ingots were rolled singly which could have been rolled either tandem or semi-tandem. The rolling schedule was therefore regrouped without altering the actual order of the ingots and estimates were made of the saving in time which could have been achieved had tandem rolling been completely adopted. These times are shown as item 15 in Table II.

The overall picture confirms the accuracy of predictions, derived from the components, of the actual rolling time. After allowing for observed delays and departures from the theoretical practice, the unaccounted time was less than 2% on each of the shifts.

INFLUENCE OF ROLLING SPEED

The speed range of the work rolls of the slabbing mill under review is 40–80 rev/min but because it was recognized that the existing steelmaking resources were inadequate to saturate fully the slabbing capacity, the management decided to reduce the potential wear and tear on the equipment by operating normally at a speed of 40 rev/min. With the prospect of an increase in the amount of material to be rolled in the slabbing mill, it was considered desirable to measure the effect of roll speed on the total time to roll an ingot in order to determine the optimum speed. Whilst an increase in roll speed might appear to be obviously advantageous in an attempt to increase output (because the time in contact with rolls could reasonably be expected to decrease), the effect of such an increase in speed on the other components in the rolling cycle must be carefully examined. It was not known for example, whether an increase in roll speed might not result in the ingot being thrown further out of the rolls—a factor which might well outweigh any advantage gained from increased roll speed.

It was accordingly decided to carry out a series of trials with the mill running at speeds of 20–30, 40, 50, and 60 rev/min. The reduction in speed to 20 rev/min took place when a generator was out for repair. The higher speeds were obtained by adjusting the field-weakening controls incorporated in the design. The fact that increased speed was obtained by field weakening might set a further limitation on the influence on the output since the maximum power available was unaltered.

During the trials, the rolling operation was broken down into the components discussed above, which were timed by means of the teleprinter equipment.

The first component of vital interest was the time in contact with rolls. Figure 13 illustrates the relationship between the length of slab and the time in contact with the rolls for each of the speeds examined. In each case the curve of best fit was a straight line, but in the interest of clarity the scatter about each line, which was reasonably constant, has been omitted. From Fig. 13, it appears that increased roll speed does result in a decrease in time in contact with rolls when the effective slab length is greater than 200 in.

The influence of the increased roll speed on the other components of the rolling cycle is shown in Table III. Examination of the means quoted showed that there was no systematic pattern and that increased roll speed did not seem to effect the rolling components adversely.

The net effect of increased roll speed would appear to be a reduction in the total time to roll, illustrated for selected ingots in Table IV. While an increase in speed from 40–50 rev/min yields approximately 10% increase in output, a similar increase from 50–60 rev/min yields only about 1% further increase in output. It should be remembered that wear and tear on the mill might be higher at increased speeds with some consequent loss of availability.

INFLUENCE OF DEEPER DRAUGHTING

In addition to varying the roll speed, the possibility of gaining some advantage from an increase in the depth of draughting is worthy of consideration. Such an increase in draughting would mean fewer passes through the mill and might result in a decreased time to roll each ingot. Accordingly, a series of trials was carried out with the mill running at its normal speed

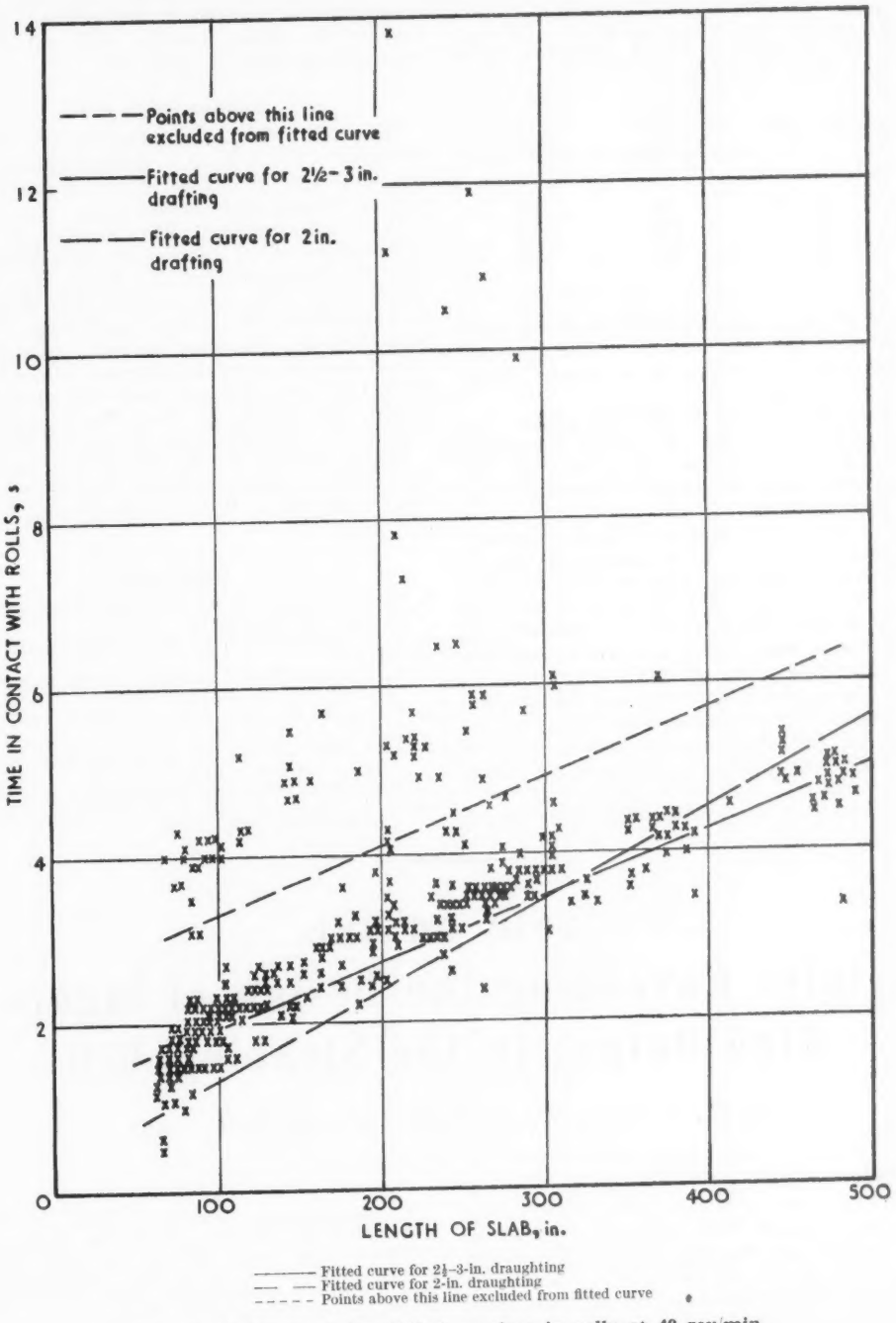


Fig. 14—Influence of draughting on time in rolls at 40 rev/min

of 40 rev/min, but with the draughting increased from its normal value of 2 in. to between 2½ and 3 in.

The influence of the deeper draughting on the time in contact with rolls is shown on Fig. 14. In this particular trial, it was only possible to observe the rolling of single ingots. The large amount of scatter indicates that the performance of the mill under these conditions was erratic. In order to fit a line to these data which is a reasonable representation of the conditions, the extreme upper points were disregarded and would be equivalent to a delay factor of 3·4 s every 5 passes. This gives a good picture of the

Table V

COMPARISON OF THE TIME TO ROLL CERTAIN INGOTS AT 40 rev/min WITH NORMAL AND DEEPER DRAUGHTING

Ingot nominal weight, tons	Slab section, in.	Time to roll single ingots normal draughting, s	Time to roll single ingots deeper draughting, s
10	39 × 8½	108	111
11·5	48 × 7½	108	118
11·5	42 × 8½	117	121
12	29 × 7	154	156

situation since the extreme scatter is due to the ingot failing to enter the rolls because of the increased draughting, thus necessitating on occasions a second or even third attempt.

It has been suggested by the Mill Management that if it was desired to utilize the deeper draughting technique, an increase in diameter of the work rolls in order to preserve the same angle of bite might very well overcome this difficulty.

Figure 14 indicates that there is little advantage under present conditions to be gained in time in contact with rolls component from increased draughting. The effect of the delay factor is to outweigh completely the advantage gained from the reduction in the number of passes required, as will be seen from the total time to roll the selected ingots quoted in Table V. During this trial it was clear that the mill was labouring under some mechanical strain and this fact, as well as the actual results obtained, indicated that nothing was to be gained from proceeding further along these lines.

It is realized that the results obtained for deeper draughting are coloured by the particular characteristics of the Abbey slabbing mill and would not necessarily be true for other mills.

Acknowledgments

The authors wish to thank the Directors of the Steel Company of Wales Limited, for permission to publish this paper and the R.T.S.C. Research Laboratory for helpful criticism of the manuscript.

The work described has involved the closest collaboration of all levels of the Mill Management; from the Superintendent, Mr. H. H. Ascough, who posed many of the questions, from the Manager, Mr. G. A. Redmore and the Assistant Manager, Mr. R. H. Slade, who gave the fullest facilities for the work to be undertaken, and from the rollermen who collaborated in the tests; the assistance of all is gratefully acknowledged. The Abbey Electrical Department also are thanked for their assistance throughout the trials.

Thanks are also due to B.I.S.R.A. for the loan of teleprinter equipment pending the delivery of the Steel Company of Wales Limited's own teleprinter equipment.

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Note on the Principles Governing the Design of Ingots for High Output in the Slabbing Mill

By H. G. Jones, P. D. Dickerson, and D. T. Steer

SYNOPSIS

It is shown that the output from a slabbing mill producing a given range of slabs can be increased by using thicker ingots. The width of the ingots has virtually no effect on the tonnage rolled, provided that no extra tilts are involved. Increase in height of the ingot (particularly at the expense of the width) also increases output. 1216

THE SHAPE of the ingot relative to the slab will clearly influence the speed of rolling, the fastest rolling being obtained from the ingot nearest in shape to the slab and therefore from an ingot with a small cross-section. On the other hand, to obtain the maximum tonnage through the mill, each ingot should be as heavy as possible and therefore, because of the physical limitations imposed by the teeming process, it is desirable that the ingot should have a large cross-sectional area. Is there an optimum compromise between these conflicting considerations?

Manuscript received 5th September, 1955.

The authors are with the Operational Research Section of The Steel Company of Wales Ltd.

Further, since most works will produce a range of slabs, how far can the number of ingots be restricted, both to reduce capital locked up in moulds and to give standardized procedures in the mould preparation bay?

Certain work has been described by Wolf[1] on the influence of ingot dimensions and weight on the out-

put of blooms. Although his work was primarily directed towards establishing a logical wage structure, it contained evidence of an optimum ingot size; however, he did not follow the optimizing influence as far as could be desired.

Once the time characteristics[2] of a particular slabbing mill have been established, it is possible to evaluate, firstly the time to roll any ingot, and secondly the rate of rolling in tons/h. Theoretical comparisons between different ingots rolled to the same slab are then readily made. This process has been carried out for the Abbey high-lift mill and has led to the conclusions described below: these conclusions only apply so long as the mill had adequate power to operate with uniform draughting on all the sections under consideration.

TIME TO ROLL AN INGOT

Figure 1 illustrates the relationship between the time to roll ingots (of weights ranging from 7 to 16 tons) and the total reduction (defined as the sum of the changes in the edge and the flat dimensions when passing from the ingot to the slab) for a wide range of slabs. Two significant points are apparent, namely:

(*a*) Six sets of passes (defined as rolling sequences requiring five tilts of the ingot) are so time-consuming relative to rolling sequences with four sets of passes that they should only be used when special quality considerations demand their use.

(*b*) There is an approximately linear relationship between the time to roll the ingot and the total reduction for the same rolling pattern.

It can be shown by elementary mathematics that the linear relationship of Fig. 1 is only rigidly correct provided that the rolling patterns for each estimate are strictly similar, that the same draughting is used on each pass, and that the ingot and slab lengths have the same values for each estimate. Most of the deviations from the straight lines of Fig. 1 are due to uneven draughting or to occasional dummy passes required to get the slab on the correct side of the mill for tilting. A smaller amount of spread in the estimates arises from slight inequalities in the ratios of the edge and flat passes used for different slabs and from different lengths of slabs. Fortuitously, however, the works' practice is sufficiently near to the theoretical requirements for the relationship to be used empirically.

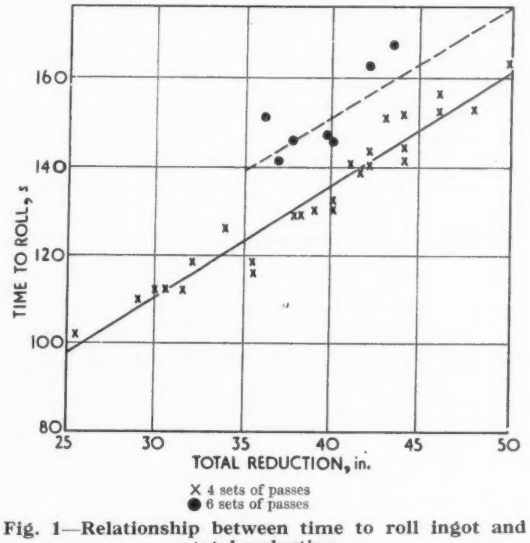


Fig. 1—Relationship between time to roll ingot and total reduction

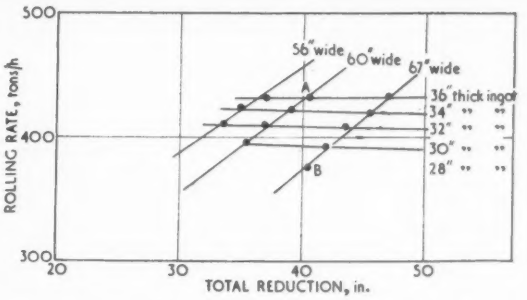


Fig. 2—Theoretical output obtained from various ingots rolled to 50-in. wide slab

For the Abbey Mill, the empirical relationship has the values

$$\text{(Time in seconds to roll ingot)} = 2{\cdot}52\ \text{(total reduction in inches)} + 34{\cdot}7 \quad \ldots\ldots(1)$$

Its use simplifies the extraction of the general principles by eliminating much of the arithmetical calculations. In converting to the output rolled per hour, it is necessary to allow an extra 6 s between ingots, but it is otherwise assumed that no delays occur in the mill. The subsequent discussion will be restricted to ingots rolled in four sets of passes. It is assumed that sufficient work is done on both the edge and the flat side of the ingot to ensure metallurgically sound steel.

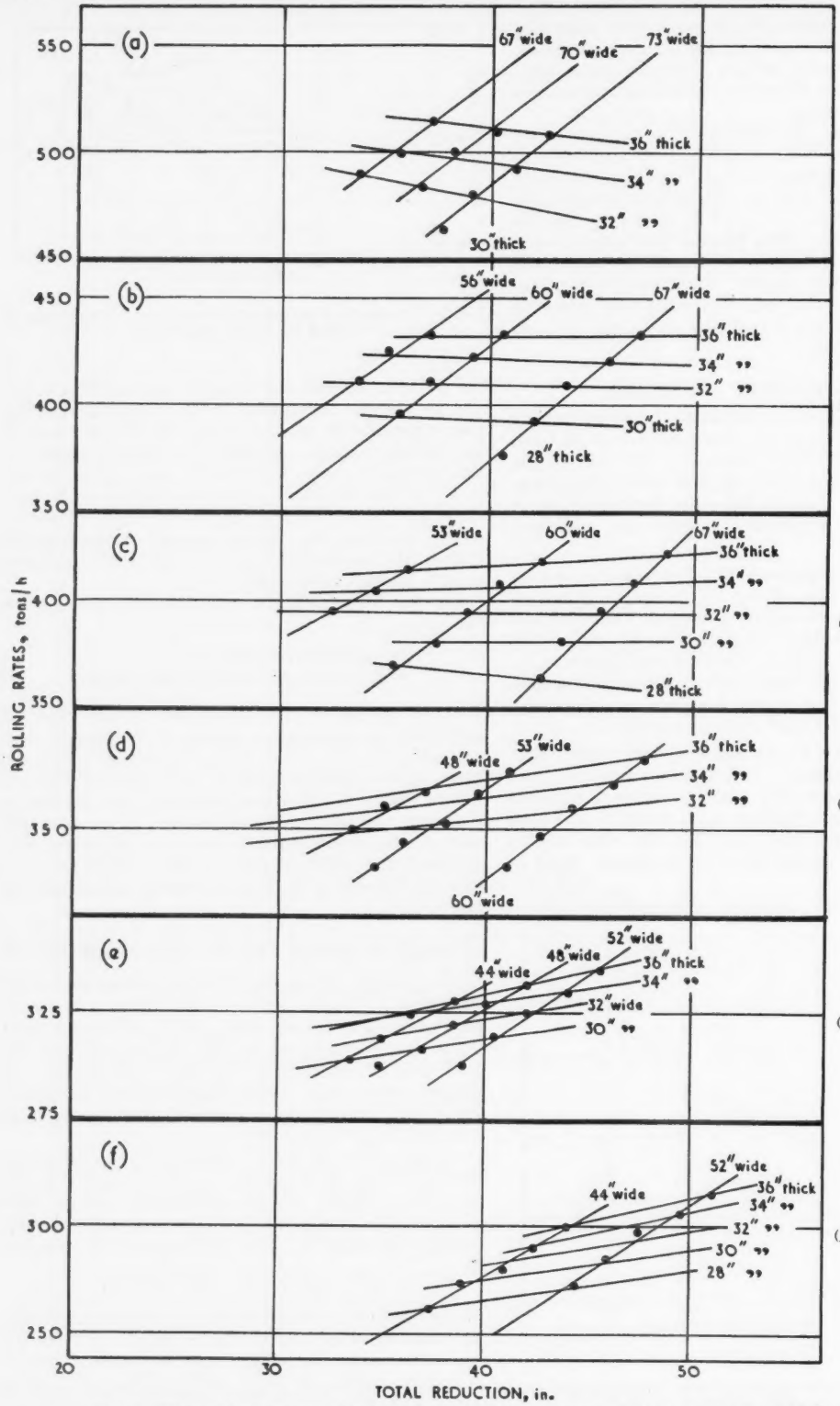
EFFECT OF WIDTH AND THICKNESS OF INGOT

The method of approach will be demonstrated by considering a range of ingots rolled to a common slab width of 50 in. and with a thickness ranging from $4\frac{1}{2}$ to 6 in. determined by the slab weight and the necessity to produce a constant slab length (or simple sub-multiples of this length), after compensating for a yield of 87%. Each of the ingots will be assumed to be 70 in. high.

Suppose ingot *A* is 17·1 tons in weight. Its cross-section (using the ingot density of 0·255 lb/in^3) will be 60 in. × 36 in. When reduced to a 50-in. wide slab, this will give a slab $5\frac{1}{2}$ in. thick (the slab density being 0·283 lb/in^3). The total amount of reduction is

$$(60 - 50) + (36 - 5\tfrac{1}{2}) = 40\tfrac{1}{2}\ \text{in.}$$

Reference to Fig. 1 shows this ingot would theoretically be rolled in about 137 s. After allowing for the 6 s between ingots, the rolling rate with ingot *A* to this slab size would be about 432 tons/h. This gives point *A* on Fig. 2.



(*a*) Rolling to 61-in. slab

(*b*) Rolling to 50-in. slab

(*c*) Rolling to 48-in. slab

(*d*) Rolling to 42-in. slab

(*e*) Rolling to 36-in. slab

(*f*) Rolling to 29-in. slab

Fig. 3—Theoretical output obtained from various ingots rolled to a series of slab widths

Table I

SUMMARY OF SELECTED INGOTS REDUCED TO A PAIR OF 50-in. SLABS

Ingot			Slab Thickness, in.	Rolling Rate, tons/h
Width, in.	Thickness, in.	Weight, tons		
67	28	13·0	4½	376
	30	13·9	5	392
	32	14·8	5½	408
	34	15·7	5½	419
	36	16·7	6	433
60	30	12·4	4½	395
	32	13·3	5	410
	34	14·1	5	419
	36	14·9	5½	432
56	32	12·4	4½	411
	34	13·2	5	424
	36	14·0	5	432

Now suppose another theoretical ingot B is 13·0 tons in weight. Its cross-section will be 67 in. × 28 in. When reduced to a 50-in. slab its thickness will be 4½ in. The total reduction is

$$(67 - 50) + (28 - 4\tfrac{1}{2}) = 40\tfrac{1}{2} \text{ in.}$$

Reference to Fig. 1 again gives a rolling time of 137 s. But owing to its smaller weight, the output from ingot B rolled to the 50-in. wide slab would be only 376 tons/h; this is shown by point B on Fig. 2.

A family of curves is propagated in this way for Fig. 2 from which it is clear that in rolling to this particular slab width of 50 in., the width of the ingot has virtually no effect on the rolling rate when compared with the thickness of the ingot.

The ingots of Fig. 2 are listed in Table I. To make a valid comparison, the table is restricted to ingots rolling to a pair of slabs. If the 60 in. × 28 in. ingot for instance is rolled to 50 in. wide, it will only produce single slab of 8½ in. thickness, but the rolling rate will be 418 tons/h. Without wishing to pursue this point further at the present stage, this obviously gives a method of increasing slabbing mill output, as long as the subsequent processes can deal satisfactorily with thicker slabs.

Families of curves are shown on Fig. 3 for the rolling of six different slab widths. In each case, increase in thickness of the ingot influences the rolling rate more strongly than does an increase in width of the ingot.

Having extracted the general principles by using the simplified times of Fig. 1, a return should be made to particular ingots because it is known that the straight line in Fig. 1 evens out certain discrepancies in rolling time arising from dummy passes. The effects of dummy passes are therefore examined by calculating the times to roll certain slabs with allowance where necessary for dummy passes. The results are plotted on Fig. 4. Dummy passes are the cause of the zig-zag effect to be seen on the rolling times of each width of slab; such passes can affect the rolling rate by as much as 30 tons/h. Figure 4

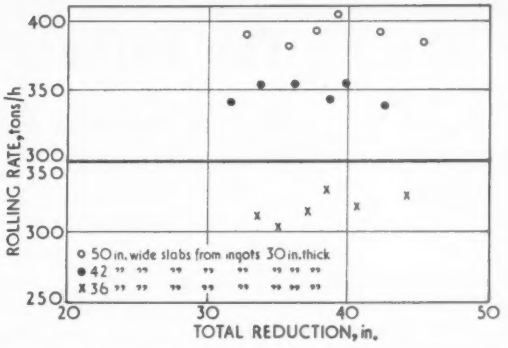


Fig. 4—Theoretical outputs after allowing for dummy passes

indicates that the influence of the width of the slab (which appeared slight in certain slabs on Fig. 3) is completely masked by dummy passes.

There is clear evidence on Figs. 2–4 of the advantages to be derived from using the thickest ingot consistent with quality. The width of the ingot on the other hand has comparatively no effect on the output measured in terms of tonnage per hour.

In fact, the best ingot will be a compromise between the best rolling rate (and therefore the thickest slab), the desire to gain optimum working in the reheating furnaces by having only a small range of slab thickness, and the need to restrict the slab weight to that suitable for subsequent pickling or handling.

EFFECT OF INGOT HEIGHT

If the height of the ingot is altered whilst preserving the same cross-section, for each inch increase in height beyond 70 in., the rolling rate is improved by approximately 1%; this increase is obviously not universally beneficial and must be considered alongside other factors. On the other hand, if the width dimension can be decreased to compensate for increase in height, so that the ingot weight remains constant, the rolling rate will be improved owing to the smaller number of edge passes which would be required. The slab would also, in this case, be equally acceptable as that from the ingot replaced.

Acknowledgments

The authors wish to thank the Directors of the Steel Company of Wales Limited for their permission to publish this paper.

The authors also wish to thank the Mill Management, Mr. H. H. Ascough, Mr. G. A. Redmore, and Mr. R. H. Slade, and the Production Department Manager, Mr. W. Grove Martin, for the helpful discussions which took place when the work was in progress.

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The Enthalpy of Pure Iron

By J. R. Pattison, B.Sc., D.I.C., Ph.D., A.Inst.P.
and P. W. Willows, B.Sc.

SYNOPSIS

An apparatus is described for the direct measurement of the enthalpy of metals at high temperatures by the method of mixtures using a water calorimeter. By a study of pure iron using this method, smoothed values of enthalpy, with respect to zero enthalpy at 0° C, were obtained for the temperature range of 1000–1650° C. The values of 3·7 cal/g for the A_4 heat of transformation and 65·5 cal/g for the heat of fusion were derived from these data. The mean specific heats of 0·161 for γ-iron, 0·159 for δ-iron in the solid phase, and 0·144 in the liquid phase were also evaluated. 1210

Introduction

A KNOWLEDGE of the enthalpy of various commercial steels is necessary for the calculation of heat balances in some steelmaking processes. Enthalpy data are required for calculations of the heat content of a cooling ingot of steel to improve the conservation of fuel in soaking pits by establishing the optimum cooling time before charging. The total heat of stainless steel and high-speed tool steel is also necessary for investigations of the process of continuous casting of these metals.

A survey of the methods of measurement of enthalpy has been made in a previous report[1] and the available published data for steel have been reviewed.[2] These two reports lead to the conclusion that the varying published results should be checked and investigations extended to steels for which no published enthalpy data is available.

This report describes an apparatus constructed for the measurement of the enthalpy of steel and the results obtained for pure iron which was investigated chiefly to establish a basis of comparison, by means of the published data for this metal, with other calorimetric investigations.

GENERAL PRINCIPLE OF THE METHOD

Where the enthalpy, rather than the specific heat, of a metal is required, the direct method of measurement by calorimetry is the more accurate. The total heats may be evaluated from a specific-heat/temperature curve by integration but not without a considerable decrease in accuracy. Conversely, specific heats may be obtained by the differentiation of total-heat/temperature curves, but with a loss in accuracy. Since, in the applications under consideration, the total heats are required, some form of calorimetry is necessary. The choice may be made from water, ice, or metal block calorimeters.

Whatever form the calorimeter may take, it must be calibrated in terms of some accepted international unit. The use of another metal with known total heat values is perhaps the worst method since this involves a summation of the errors of two investigations. The assumption of unit specific heat for water is only strictly valid at 15° C, but a small correction may be made for the specific heat at other temperatures, although this again involves summation of errors. When the calibration procedure is used for a water calorimeter, it is necessary to use enough water so that the errors in calculating the water equivalent of the calorimeter and components are comparatively small. All these indirect calibration methods lead to further errors unless the thermometer used to measure temperature changes in the calorimeter has been accurately standardized.

The calibration of an ice calorimeter depends on the difference in the volumes of ice and water at 0° C; but the poor reproducibility of the published measurements of the density of ice make an electrical calibration essential. The electrical energy may be added to the calorimeter by means of a built-in heater, and this calibration method in terms of international units of electrical energy is the most direct and accurate procedure. The more complex mechanism of heat transfer which occurs in a metal block calorimeter makes a direct electrical calibration impossible for this type, but the method is suitable for water—as well as ice calorimeters. In a water calorimeter, when a heater is used for calibration, the thermometer used to measure temperature changes acts merely as an indicator and need not be standardized to measure temperatures exactly.

The consideration of accurate calibration techniques reduced the choice of calorimeter design to one using water or ice. The relative simplicity of the water calorimeter made this the final choice but this was subject to a preliminary investigation of steam loss which is one of the objections sometimes made to this type. If any steam is produced by the introduction of a hot specimen into a water calorimeter, and if this steam escapes, then a considerable heat loss could be caused. This loss may be avoided by simple design criteria for the calorimeter, as described in Appendix I. A water calorimeter was adopted.

The general plan of the experimentation may be described in terms of the following equations. When a mass M_i of iron at a temperature T_1°C, enclosed in an alumina crucible of mass M_a at the same temperature, is dropped into a water calorimeter at an initial temperature t_0°C, equilibrium is attained at a maximum water temperature of t_1°C. At this condition

$$M_i I_{t_1}^{T_1} + M_a A_{t_1}^{T_1} - M_a F(T_1) = w_1 (t_1 - t_0) + f(t_1) \ldots\ldots (1)$$

where the respective heat losses of unit mass of

Paper P/13/55 of the Physics Department of the British Iron and Steel Research Association, received 20th August, 1955.

Mr. Willows was formerly at the Physics Department where Dr. Pattison is in the Fuel Technology Section.

iron and alumina are $I_{t_1}^{T_1}$ and $A_{t_1}^{T_1}$. The heat lost by the iron and the alumina crucible during the short time of transition between the furnace and the calorimeter is assumed to involve the crucible only and to be represented by a complex time function of the temperature $F(T_1)$. The water equivalent of the calorimeter, water contents, thermometer, and accessories is w_1 over a temperature range of t_0 to t_1°C the heat lost by the calorimeter in rising from t_0°C to t_1°C is represented by a function $f(t_1)$ of temperature and time.

In order to eliminate the heat contents of the alumina crucibles it is necessary to carry out blank experiments with empty crucibles. In this case

$$M_a A_{t_2}^{T_2} - M_a F(T_2) = w_2(t_2 - t_0) + f(t_2) \quad \ldots\ldots\ldots (2)$$

The calorimeter may be calibrated by introducing a known quantity E_3 of electrical energy through a built-in heater, and here

$$E_3 = w_3(t_3 - t_0) + f(t_3) \quad \ldots\ldots\ldots (3)$$

The above equations will be simplified if $f(t)$ can be eliminated and w is a constant independent of temperature, i.e. $w = w_1 = w_2 = w_3$. Under these circumstances E_3 and t_3 are linearly related;

$$[M_a A_{t_2}^{T_2} - M_a F(T_2)]$$

can be obtained in terms of t_2 in a simple relation, which, if $A_{t_2}^{T_2}$ is a linear function of T_2 and $F(T_2)$ is small, may be linear; and

$$[M_i I_{t_1}^{T_1} + M_a A_{t_1}^{T_1} - M_a F(T_1)]$$

can be obtained in terms of t_1.

Hence, from the relationships between E and t, A and t, and $I + A$ and t, I (the enthalpy of iron) may be evaluated in terms of electrical energy E.

The above conditions may be satisfied in the following way. The function $f(t)$ may be eliminated by measuring the rate of cooling of the calorimeter, subsequent to attaining the maximum temperature in an experiment, and correcting the maximum temperature to the value which would have been obtained if no loss of heat due to conduction, radiation, or evaporation had occurred. The variation in w may be made negligibly small by choosing the range of temperatures for the water in the calorimeter between 30° and 40° C. The specific heat of water over the range 0–50° C has been measured by four sets of observers: Callendar and Barnes,[4–7] Jaeger and Steinwehr,[8] Osborne, Stimson, and Fiock,[9] and Osborne, Stimson, and Ginnings.[10] Although there is some disagreement between the observers, they agree in general on the form of the specific-heat/temperature curve, and that a minimum occurs between 30° and 40° C. The ranges of specific heat values obtained by these workers vary from 0·23 to 0·34% over the 10–20° C range but only 0·008 to 0·026% over the 30–40° C range.

DETAILED DESCRIPTION OF THE APPARATUS

The complete apparatus consists simply of a furnace, in which the iron specimens may be heated to a desired temperature, and a water calorimeter into which the specimens may be dropped to apply the method of mixtures for the heat contents of the iron. A more detailed description of the individual parts of the apparatus is given below.

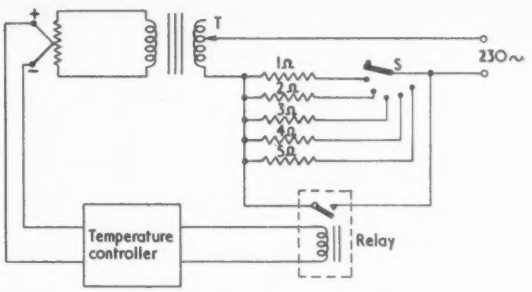

Fig. 1—Furnace control system

The Furnace

The furnace was of the graphite grid type, described elsewhere,[11] but the design was modified by introducing an alumina tube as a liner. The space between the alumina liner and the graphite heater was packed with alumina powder to reduce the possibility of carbon diffusing into the furnace tube. This reduces the likelihood of contamination of Pt/Pt–Rh couples, inserted into the tube, by platinum silicides catalysed by carbon[12] in the presence of sulphur.

The recrystallized alumina furnace liner was 3 cm int. dia. and 61 cm long, and a substantially uniform temperature could be maintained over the centre portion. The temperature attained in this centre portion was controlled by the system illustrated in Fig. 1. The controlling Pt/Pt–13% Rh thermocouple was placed in an alumina sheath between the alumina liner and the graphite heater. The e.m.f. from this couple was fed to a commercial temperature controlling unit which, by means of a relay, opened or closed a switch by-passing the switch S when the e.m.f. exceeded or fell short of the initial setting of the controller.

In each run, the switch S was set open initially and the tapping T, on the primary winding of the furnace transformer, was set so that the maximum heating rate was used. When the e.m.f. preset on the controller was reached, the controller operated the relay. After a short soaking period for the furnace as a whole, the controller attained its optimum controlling performance using the relatively coarse on–off switching. At this point the tapping T was adjusted and the switch S was set to one of the bank of series resistances so that the controller relay changed the electrical input to the furnace heater within narrow limits. In this way a fine control of the specimen temperature was established.

The furnace was operated with the central tube vertical and with both ends closed. The upper end was closed by an alumina plug and the lower end by a water-cooled door which incorporated a valve through which nitrogen was passed into the furnace tube throughout an experiment.

The Suspension Mechanism

The method of suspending the iron specimens in the furnace, so that they could be quickly released when required, is illustrated in Fig. 2. The iron was supported in a conical crucible of recrystallized

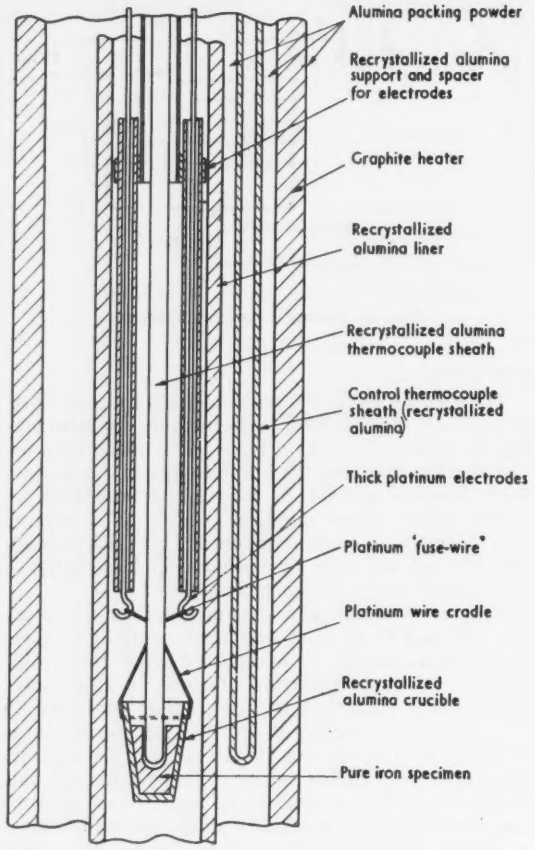

Fig. 2—Suspension of specimen in furnace

alumina and suspended by a platinum wire cradle from a platinum wire stretched tautly between two platinum electrodes. Application of a potential difference across the two electrodes fused the connecting wire and released the crucible, specimen, and cradle. (0·2 mm dia. wire was used for the fuse at temperatures up to 1500° C and 0·3 mm dia. wire at higher temperatures.) Preliminary experiments were carried out to determine the minimum potential difference necessary to fuse the wire at different temperatures to reduce the amount of platinum vaporized during the process. Some of the vapour condensed on the alumina support and spacer for the electrodes and to prevent a conducting path being produced by the accumulation of platinum deposit across the electrodes after a series of experiments, the lower spacer was set as far above the electrode ends as possible.

The iron specimens were machined to fit snugly into the crucibles and had an off-centre hole drilled into the upper ends to accommodate a thermocouple sheath. The accurate measurement of the specimen temperature presents great difficulty. Wüst, Meuthen, and Durrer[13] used a thermocouple in a sheath alongside the specimen crucible. This arrangement avoids any loss of metal in the molten state due to adhesion on a sheath dipping into the specimen, but involves error due to the fluctuation of the furnace wall temperature which, however finely controlled, will be greater than the fluctuation of the specimen temperatures. Jaeger and Rosenbohm[14] used a special crucible lid incorporating a small sheath. Although this dipped into the metal, it was dropped with the specimen and crucible, leaving the thermocouple junctions uncovered. This is probably the best method to use, but, owing to the shortages of recrystallized alumina ware, it was not adopted. In practice, with the thermocouple sheath dipping into the metal, loss due to adhesion was found to be small enough to be neglected.

The alumina support was designed so that the depth of both the electrodes and the tip of the thermocouple sheath into the furnace were adjustable, so that the specimen could be placed in the region of minimum temperature gradients in the furnace tube.

The Calorimeter

The calorimeter, as illustrated in Fig. 3, consisted of a copper vessel 23 cm long and 10 cm in diameter with a triangular fillet let into one side. The purpose of the fillet was to accommodate a mercury-in-glass thermometer 77 cm long without making the distance between the furnace and the calorimeter greater than necessary.

The calorimeter was enclosed in a water-tight brass container which was in turn immersed in a continuously stirred water bath. The temperature of the bath was maintained at 32° C to establish reproducible conditions of temperature round the

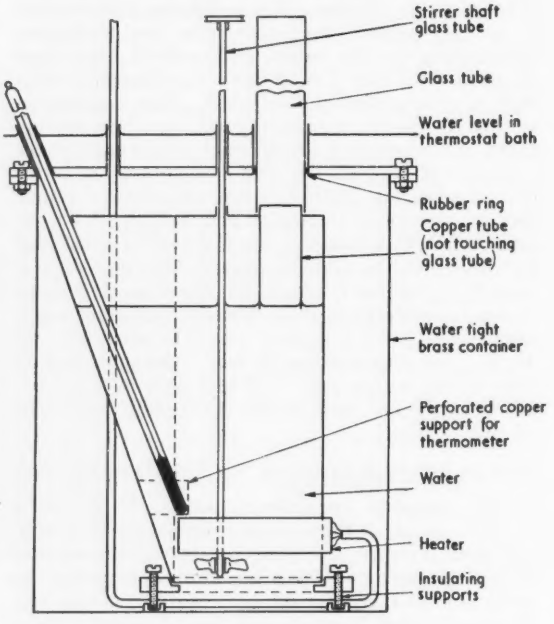

Fig. 3—Calorimeter assembly

calorimeter. A toluene regulator with a proportioning head operating the 750-W electric immersion heater, by a hot wire relay system, stabilized the water bath temperature to $\pm$ 0·005° C.

As shown in Fig. 3, the calorimeter was fitted with a copper tube fixed to the lid, which just entered the surface of the water contents. This prevented the loss of water by splashing as the specimen fell under gravity into the calorimeter. A glass tube fixed above the copper tube to the lid of the brass container served as an indicator of the efficacy of this anti-splash device. The calorimeter incorporated a stirrer with a low-conducting glass tube shaft and was supported on an insulating stand making a small area of contact with the calorimeter. An electric heater was built into the calorimeter for calibration purposes.

The Calorimeter Calibration Circuit

The calibration circuit for the calorimeter is illustrated in Fig. 4. The heating current, obtained from a bank of batteries, is passed initially through a dummy heater which is a replica of the heater built-in to the calorimeter. The current is measured in terms of the potential difference across a known resistance in the circuit and when the current reaches a steady value it is switched to the calorimeter heater. The potential difference across the heater is determined by reducing the value by 100 : 1 in a divider and using a precision millivolt potentiometer. The evaluation of the electrical energy supplied is outlined in Appendix II.

The dummy heater allows the measuring instruments to be set to the correct range scales before the current is switched to the calorimeter heater. It also allows a check on the current stability before a measuring run, and reduces the current surge produced during the switching.

EXPERIMENTAL RESULTS

The experimentation involves a number of procedures which may be carried out independently and these will be described separately.

Furnace Technique

All measurements of temperatures inside the furnace tube were carried out with Pt/Pt–13% Rh thermocouples enclosed in recrystallized alumina sheaths. The temperature scale was defined with reference to the 1948 International Temperature Scale by checking

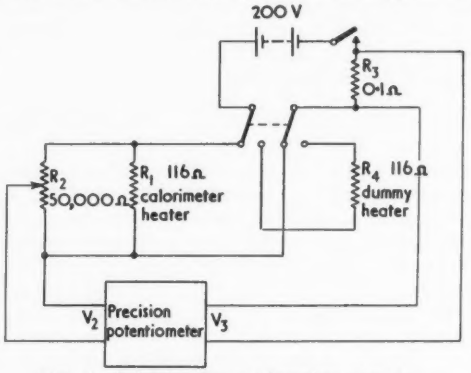

Fig. 4—Calorimeter calibration circuit

Table I
ANALYSIS OF IRON SAMPLE, %

Carbon	0·0023
Silicon	0·002
Manganese	< 0·005
Sulphur	0·003
Phosphorus	0·001
Nickel	< 0·010
Chromium	0·001
Copper	0·004
Aluminium	0·001
Oxygen	0·0027
Nitrogen	0·0014
Hydrogen	0·000005
Total detected impurity	0·034

the couples against gold (1063° C) and palladium (1552° C) points.

The temperature distribution along the alumina furnace tube was measured at various controlled temperature maxima with the specimen support in position. A section of tube 4 cm in length with its centre at the maximum recorded temperature was found to have a temperature range of less than 1° C up to a temperature of 1400° C, and not exceeding 2° C up to 1600° C. This section, having been located, was henceforth used for heating the specimens.

The iron used in the enthalpy determinations was vacuum-melted, hydrogen-treated, high-purity Swedish iron produced in the N.P.L. as described by Hopkins, Jenkins and Stone.[15] The composition of the sample is given in Table I.

A discontinuous set of values of enthalpy at different temperatures cannot give as accurate an indication of the temperatures at which allotropic changes occur in a metal as a thermal analysis using continuous temperature exploration. Therefore a thermal analysis of the iron under investigation was carried out to locate the A_3, A_4, and melting points. The specimen was suspended in the furnace in the normal way and its temperature brought up to 900° C, where it was allowed to soak for 20 min after the fine control of the furnace had established this temperature within a cyclic change of $\pm$ 1° C. The controller was then set so that initially the specimen received heat at such a rate that its temperature rose $\frac{1}{2}$° C/min. The specimen temperatures were noted at 20 s intervals until a temperature of 930° C was attained. The procedure was then repeated over the temperature ranges 1370–1410° C and 1520–1540° C. A further set of measurements was taken under a cooling rate of $\frac{1}{2}$° C/min over the same ranges. The following arrest points were indicated by the thermocouple

Ac_3 910·5° C Ar_3 909·9° C

Ac_4 1400·0° C Ar_4 1399·8° C

Melting temperature 1532·8° C. Freezing temperature 1533·0° C. These figures show the A_3, A_4, and melting points to be 910° C, 1400° C, and 1533° C respectively.

The published values for the transformation temperatures of pure iron are reviewed in Appendix III and an analysis of these leads to selected values which are in good agreement with the figures now given.

Calorimeter Technique

As illustrated in Fig. 3 the calorimeter was enclosed in a water-tight container submerged in a water bath at a temperature of $32{\cdot}000 \pm 0{\cdot}005^\circ$ C. Fifteen minutes before it was intended to drop a specimen into the calorimeter, 1500 ml of fresh, air-free, distilled water was introduced into the calorimeter through the copper tube in the lid. The temperature of this water, which was stirred continuously at a constant rate, was then raised by a controlled electric current passed through the built-in heater until it reached $32{\cdot}000^\circ$ C. The current was switched off and the water contained in the calorimeter remained at this temperature until a specimen was dropped into it.

When a hot specimen of iron in an alumina crucible, or an empty crucible, was introduced into the calorimeter the rapid heat transfer rate to the water, accelerated by rapid mechanical stirring, caused the thermometer reading to reach a maximum in a short time (a maximum temperature rise of 7° C was reached in 50 s and 2° C in 20 s). During this process the calorimeter loses heat by conduction, convection, radiation, and evaporation, and gains heat from the immersed specimen until, at the maximum thermometer reading, heat is being received at the same rate as it is being lost. The loss of heat from the calorimeter may be eliminated by Rumford's method, in which the initial calorimeter temperature is below that of the surroundings and the final calorimeter temperature above that of the surroundings. The rate of heat transfer from the specimen is not constant so that the initial and final temperature differences are not identical. The calculation and adjustment of the initial temperature differences, for complete heat loss compensation, was not practicable with the limited quantity of pure iron available so that this method was not used.

As the temperature of the water in the calorimeter rises and falls, the thermometer temperature lags, so that the maximum thermometer reading is below the maximum temperature attained by the water. This temperature discrepancy does not affect the method when a heating coil is used to calibrate the calorimeter since the thermometer only acts as an indicator by which the electrical energy input to produce a given increase in the temperature reading may be related to the known temperature and mass of a specimen producing the same temperature rise.

There are two main sources of discrepancy between electrical heating and the process of heating the calorimeter by dropping in a hot specimen. Firstly, the rate of heat exchange will be exponential in the case of the specimen and practically linear in the case of the heater. Secondly, in practice the heater cannot be designed so that the time taken to produce a given temperature rise is equal to the time taken by a given specimen to attain equilibrium in the calorimeter. To reduce these differences, a standardized procedure was followed in which the time θ_1 between the first immersion of the specimen in the calorimeter and the thermometer attaining a maximum reading t_1 was measured. Readings of the thermometer, t, were taken at 20 s intervals, after this maximum had been reached, for a period of 15 min. The rate of cooling $\frac{dt}{d\theta}$ was evaluated by difference and a regression line of $\frac{dt}{d\theta}$ against t was calculated. From this line the rate of cooling $\left(\frac{dt}{d\theta}\right)_1$ at the maximum temperature t_1 can be obtained, and $\frac{1}{2}\left(\frac{dt}{d\theta}\right)_1 . \theta_1$ added to t_1 as a correction for the heat lost during the temperature rise to a maximum. The duration of this temperature rise was too short for accurate measurements of the temperature to be made before the maximum was reached so that a more systematic correction for heat loss could not be applied.

This cooling correction was applied to all measurements with the calorimeter for immersed specimens or electrical calibrations and thus the function $f(t)$ in equations (1), (2), and (3) can be removed by giving corrected values to t_1, t_2 and t_3. At the maximum water temperature, heat is still being lost by the specimen so that its temperature is still higher than that of the water. Thus, it is not quite correct to use t_1 on both sides of equations (1) and (2); but since $(T_1 - t_1)$ and $(T_2 - t_2)$ are large, the small error in specifying the specimen temperatures by t_1 and t_2 becomes negligible.

The calibration of the calorimeter was carried out by passing a measured quantity of electrical energy through the built-in heater. The circuit is given in Fig. 4 and the method is described more fully in Appendix III. A range of times of flow of the heating current was used so that the temperature changes were spread at intervals through the range $2\frac{1}{2}^\circ$ C to 7° C, which corresponded to the range of temperature changes occurring in the calorimetric investigation. The electrical heater took about three times as long as a hot specimen in producing a given temperature rise so that the corrections for the heat lost during the rise time were in the same ratio. The corrections were of the order:

0·028° C	for a 7° C	rise in	50 s	produced	by a hot	specimen
0·007° C	,, ,, 3° C	,, ,,	20 s	,,	,, ,, ,,	,,
0·081° C	,, ,, 7° C	,, ,,	140 s	,,	,, electrical heating	
0·019° C	,, ,, 3° C	,, ,,	60 s	,,	,, ,,	,,

The steady initial and momentarily steady maximum water temperatures were measured to 0·001° C, so that the temperature rise was measured to 0·0015° C. The temperatures measured during the cooling period after the maximum were slowly changing so that a reduced accuracy of 0·002° C in their measurement was caused. However, Newton's Law of Cooling applied and the plot of cooling rates and time resulted in an improvement in accuracy so that the main source of error in the heat loss correction was in the time of rise to the maximum temperature. Although the chronometer was positioned behind the thermometer, so that both the mercury meniscus and the chronometer hand could be viewed simultaneously, an uncertainty of ± 2 s in the time of rise to maximum was unavoidable. The heat loss corrections were therefore accurate to 0·001° C only, and the summation of the errors leads to an accuracy of

0·002° C for the corrected temperature rise in the calorimeter.

To make the calibration as exact as possible the same procedure in setting up the calorimeter was used before either a calibration or an enthalpy determination, so that the influence of indeterminable inaccuracies like evaporation from the calorimeter was minimized. The rate of revolution of the stirrer was kept constant so that the heat transfer conditions were reproducible throughout. If the assumption of a linear rate of heating by the hot specimen caused an additional error of 10% in the estimation of the heat loss correction the resulting additional error in the corrected temperature rise is less than 0·05%.

In all, sixteen calibration measurements were made interposed between normal calorimetric runs. The plot of electrical energy input E against corrected temperature rise $(t - t_0)$, where t_0 was the initial calorimeter temperature of 32·000° C, showed a linear relationship and the regression line, which is the generalized form of equation (3), $E_t = w\,(t - t_0)$ was evaluated.

The constant w had a value 6702·1 abs. joule/°C, but although the abs. joule is the standard unit of energy by international agreement, the change to calories was made to simplify comparison with the extant enthalpy data. Hence, using 1 cal = 4·1833 abs. joule, $E_t = 1602{\cdot}1\,(t - t_0)$ cal. The estimated accuracy of w is $\pm 0{\cdot}5$ cal/°C and considering the accumulated errors in $(t - t_0)$, when measured after electrical heating and a calorimetric drop, the error in E becomes 0·1% for $(t - t_0)$ of the order 7° C and 0·15% for 3° C.

Blank Crucible Experiments

It is necessary to use crucibles when carrying out a calorimetric investigation of liquid iron; and to avoid discontinuity in the experimentation the solid specimens were also suspended in crucibles. Recrystallized alumina crucibles were used and blank experiments with empty crucibles must be made to obtain the enthalpy of pure iron by difference. The empty crucibles were suspended in the furnace in the same position and in the same way as when they contained iron, but the thermocouple sheath was lowered to touch the bottom of the crucible. The only other difference was that the empty crucible was allowed to soak for 30 min, instead of the 20 min allowed when loaded, after its temperature had been established within a cyclic change of ± 1° C. This extra precaution was taken because the empty crucible was not in such good contact with the thermocouple sheath as were the iron specimens.

Each blank calorimetric experiment leads to an equation of the form

$$M_a\left[A_t^T - F(T)\right] = w\,(t - t_0) = E \ldots\ldots\ldots \quad (4)$$

which is a combination of equations (2) and (3) simplified by using the results described above. To obtain this relation it is necessary to make a small correction for the heat introduced into the calorimeter by the platinum suspension. The enthalpy of the measured mass of this material was obtained from the equation derived in Appendix IV. The mass of platinum was about 0·4 g compared to 10 g of alumina, so that a correction to E of 0·5% or less was entailed. The error in the measurement of the mass of platinum is negligible; the close agreement between the values of enthalpy tabulated in Appendix IV indicate that the derived values of enthalpy may be accurate to 1%, and the heat lost by the platinum in transit from the furnace to the calorimeter is less than 2%. Hence the error introduced into the value of E by making the correction is less than 0·01%.

Table II

ENTHALPY RESULTS FOR EMPTY CRUCIBLES

T° C	$(A-F)_0^T$ cal/g
1007·6	277·92
1026·9	284·09
1106·9	309·52
1152·1	322·84
1208·4	340·12
1243·2	350·67
1291·6	364·99
1343·3	381·72
1399·2	398·71
1431·7	407·22
1448·5	413·01
1457·0	416·92
1465·2	418·58
1495·5	427·86
1504·1	430·21
1508·2	432·43
1528·1	437·05
1584·3	454·90

Each blank experiment led to a value for $\left[A_t^T - F(T)\right]$ and to obtain values for this expression for all the values of T in the range of investigation it was necessary to establish the relationship between $\left[A_t^T - F(T)\right]$ and T. However t was not constant but varied from one experiment to another so that it was necessary to refer the enthalpy to the common temperature 0° C for each value of $\left[A_t^T - F(T)\right]$. Since t was always less than 40° C, $F(t)$ is negligible, and equation (4) may be rewritten, with a small change of notation,

$$\left[A_t^T - F(T)\right] + A_0^t = (A - F)_0^T = E + A_0^t$$

The values of A_0^t were taken from an equation derived from previously published work in Appendix V which is probably accurate to 1% over the 30–40° C range. Since A_0^t represented an addition of less than 2%, the correction of the enthalpy to a common reference temperature did not introduce an appreciable error.

Eighteen blank experiments were carried out and the results are given in Table II.

These experiments were not carried out in the order of tabulation but in a random fashion, interspersed between iron determinations to reduce systematic errors.

A plot of $(A - F)_0^T$ against T for the range investigated showed a linear relationship and a regression line evaluated for these results had the equation:

$$(A - F)_0^T = 30{\cdot}610\left(\frac{T}{100}\right) - 29{\cdot}96 \text{ cal/g}$$

The standard deviation of the experimental values about this line was 0·54 cal/g.

Table III
ENTHALPY RESULTS FOR IRON

Temperature T° C	Enthalpy I_0^T cal/g
γ-iron	
1007·4	159·53
1053·0	166·51
1087·4	172·57
1147·1	181·23
1205·2	192·31
1240·5	196·94
1291·2	205·06
1327·9	210·42
1362·4	217·24
1384·6	220·02
δ-iron, solid phase	
1417·5	229·05
1447·1	235·26
1464·9	235·42
1478·1	238·96
1482·6	239·02
1502·1	242·44
1507·7	243·26
1518·8	245·90
1519·8	245·58
δ-iron, liquid phase	
1540·1	313·55
1551·1	315·76
1553·9	315·70
1555·4	315·49
1567·3	318·24
1568·4	318·64
1575·4	319·93
1578·5	319·26
1590·2	321·88
1595·3	322·08
1605·5	323·88
1609·9	323·61
1620·6	326·52
1628·3	326·15
1646·0	328·78

The function $F(T)$, representing the heat lost by unit mass of the crucible during its descent from the furnace into the calorimeter, cannot be accurately evaluated; but a generous estimate of the magnitude of the loss indicated that $F(T)$ had a value less than 0·3% of A_0^T at 1600° C and less than 0·15% at 1000° C. Hence $(A - F)_0^T$ may be taken as a measure of A_0^T with a systematic error of 0·1–0·3%. A comparison of the values of A, uncorrected for this error, with other published values is given in Appendix VI. The values of A are between 2% and 4% higher than the biggest values so far reported. No explanation for this is immediately apparent but differences up to 5% occur between other sets. The mean specific heat 0·306 given by the slope of the $(A - F)_0^T$, T curve has the same value as the average of the four values derived from other work.

Experiments with Pure Iron

The details of the calorimetric procedure have already been described. Each experiment with a crucible containing iron led to the following identity:

$$M_i\, I_t^T + M_a(A - F)_t^T + M_p\, P_t^T = w\,(t - t_0) = E_t$$

where M_i, M_a, and M_p were the masses of the pure iron, alumina crucible, and platinum suspension respectively and I_t^T, A_t^T, and P_t^T the enthalpies of iron, alumina, and platinum at T° C with respect to zero at t° C, the maximum calorimeter temperature. It was assumed that all the heat lost during transit from the furnace to the calorimeter was given up by the crucible and a negligible quantity of heat was lost by the iron.

The equation may be rewritten

$$M_i\left(I_0^T - I_0^t\right) + M_a\left(A_0^T - A_0^t - F\right) + M_p\left(P_0^T - P_0^t\right) = E_t$$

so that all the enthalpy values are with respect to zero at 0° C.

Numerical values for $(A - F)_0^T$ were derived from the equation given above. The small additional terms P_0^T, P_0^t and A_0^t were evaluated from the equations given in Appendixes IV and V. The mass of iron M_i used was 17 g at temperatures above 1400° C and 22 g at lower temperatures. The heat content of the iron specimen was of the same order as the heat content of the alumina crucible in all the experiments.

To express the enthalpy of iron with respect to zero enthalpy at 0° C, the further term I_0^t for the enthalpy at t° C must be evaluated. An equation for this variable is derived in Appendix VII. The value of I_0^t was always less than 2% of the value of I_t^T so that an inaccuracy in I_0^t of 1% does not introduce an error of substantial magnitude.

The effect of the immersion of the hot specimen in the calorimeter water was to produce a dull grey surface finish which appeared to protect the specimen from subsequent rusting when exposed freely to the atmosphere. The change in weight of the specimen brought about by a calorimeter experiment increased with increase in the specimen temperature to a maximum of 0·01% above 1500° C. Analysis of the iron after experiment showed that no change in composition had occurred. No detectable change in weight of the crucible was discovered. No crucibles or iron specimens were used more than once.

Thirty-four enthalpy measurements, including 15 above the melting point, on pure iron were carried out in a random order of temperature. The results obtained are given in Table III.

Regression lines computed for these results have the following equations with standard deviations σ.

1000–1400 °C (A_4), γ-iron

$$I_0^T = -2{\cdot}94 + 161{\cdot}16\left(\frac{T}{1000}\right) \text{ cal/g},\ \sigma = 0{\cdot}54$$

1400–1533° C (Melting point), δ-iron

$$I_0^T = 3{\cdot}97 + 158{\cdot}88\left(\frac{T}{1000}\right) \text{ cal/g},\ \sigma = 0{\cdot}78$$

1533–1650° C, δ-iron

$$I_0^T = 91{\cdot}60 + 144{\cdot}44\left(\frac{T}{1000}\right) \text{ cal/g},\ \sigma = 0{\cdot}57$$

The latent heat of fusion, obtained as the difference between the enthalpy values given by the two equations for δ-iron at the melting temperature 1533° C, was 65·50 cal/g $\sigma = 0{\cdot}57$.

Similarly, the heat of transformation at the A_4 point (1400° C) was found to be 3·72 cal/g $\sigma = 0{\cdot}75$.

A comparison of smoothed values of enthalpy from the equations above is made with other reported values in Table IV. The column of average values was obtained in a previous report[1] from selected published data; and in the same report the work of Oberhoffer and Grosse[16] was recommended as the most reliable of the published papers on this subject.

The N.P.L. enthalpy data were obtained from a publication[17] giving the results obtained by Awbery and Griffiths,[18] Awbery and Challoner,[19] and Pallister,[20, 21] with pure iron of the same composition as that used to obtain the enthalpies given in this report. The agreement between the reported values and the N.P.L. values improves from a difference of 1·5% at 1300° C to 0·4% at 1000° C. Unfortunately, insufficient material was available for further determinations of enthalpy in the neighbourhood of the A_3 point, since here the different N.P.L. experimental methods meet, and there is also some disagreement in the temperature of the transition.

The tabulated values of Oberhoffer and Grosse were evaluated from the equations of smoothed values as published, except at temperatures above the melting point where no equation was given and a regression line was computed for the five experimental values. The latent heat of fusion is in fair agreement with that now reported. Oberhoffer and Grosse's smoothed enthalpy curves appear to have been obtained using an assumption that the specific heat of β-iron is the same as that of γ-iron. This has conditioned the curves but if regression lines are computed for the original experimental points, different curves are obtained in which the A_4 point becomes a discontinuity in the slope of the enthalpy/temperature curve which does not involve a heat of transformation. The latent heat of fusion is also reduced to 64·1 cal/g by this recalculation.

Table IV

COMPARATIVE ENTHALPY VALUES FOR IRON

Temperature, °C	Enthalpy cal/g			
	Average Values[1]	N.P.L. Combined Values[17]	Oberhoffer and Grosse[16]	Pattison and Willows
1000	165·4	158·8	170·0	158·2
1050	172·9	165·7	177·3	166·3
1100	180·4	172·9	184·6	174·3
1150	187·9	180·2	191·9	182·4
1200	195·4	187·8	199·2	190·5
1250	202·9	195·5	206·6	198·5
1300	210·4	203·5	213·9	206·6
1350	217·9		221·2	214·6
1400	225·4		228·5	222·7
A_4 heat of transformation	2·0		2·5	3·7
1400	227·4		231·0	226·4
1450	237·5		239·3	234·4
1500	247·5		247·5	242·3
1528			252·1	
Heat of fusion			64·4	
1528			316·5	
1530	253·5			
Heat of fusion	62·9			
1530	316·4			
1533				247·5
Heat of fusion				65·5
1533				313·0
1550	319·3		319·3	315·5
1600	326·5		326·5	322·7
1650				329·9

APPENDIX I

Heat Transfer in Calorimeter Fluids

When a calorimeter is used, any loss of the calorimetric fluid by sudden evaporation after the introduction of the solid specimen can cause a considerable error. For example, the heat lost by converting $\frac{1}{10}$ cm³ of water at 30° C into steam is greater than the heat required to raise the temperature of 1200 cm³ of water through 0·05° C. To be able to assume simple formulæ for the rate of cooling of a calorimeter small temperature changes of the order of 5° C must be used. Hence, for a calorimeter containing 1200 cm³ of water, the loss of $\frac{1}{10}$ cm³ in the form of steam represents a 1% error in the measurement of the temperature rise caused by the addition of a specimen.

There is a limited possibility of using other readily available liquids since only a few have higher boiling temperatures than water and these are all inflammable. However, the characteristics of a silicone oil with a flash point at 315° C were examined. If conduction is the only mechanism of heat transfer, then a criterion D of the merit of the calorimeter fluid is given by the product of thermal conductivity K and the difference between the boiling temperature T and the initial calorimeter temperature t

$$D = K\,(T - t)$$

The ratio of D for water to D for the oil is 0·9 so that the oil would appear to give a slight improvement. However, the main heat transfer will occur as a result of convection and in this case the criterion of merit V may be shown[3] to be

$$V = \frac{\rho s \alpha}{K\nu}\,(T - t)$$

where ρ is the density, s is the specific heat, α is the coefficient of cubical expansion, and ν is the kinematic viscosity of the fluid.

The ratio of V for water to V for oil, using mean values for the variables over the ranges of temperature considered, is 4·3; so that, for convective heat transfer, the water is better than the silicone oil.

A number of experiments were carried out to investigate the formation of steam in a water calorimeter. At the maximum temperature of the specimen which is to be studied, the temperature rise in the calorimeter should be arranged to be large enough for accurate measurement without being so large that the cooling curve of the calorimeter becomes complex. If then the temperature rise of 5° or 6° C is chosen, the ratio of the specimen weight to the weight of water is fixed. With this ratio established, a number of experiments were carried out in which specimens were dropped into cylindrical vessels of different cross-sectional areas. It was found that steam was only liberated when the depth of water was considerably less than the diameter of the vessel, i.e. when relatively stagnant sections of the water existed.

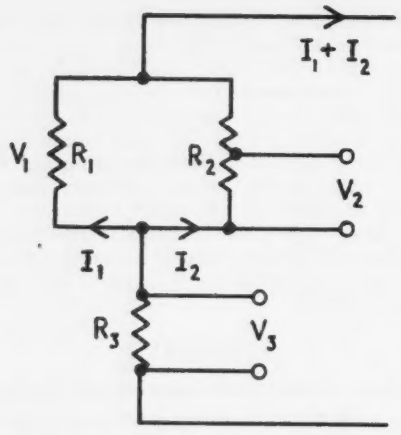

Fig. 5—Calorimeter calibration circuit detail

The conclusion was reached that mean temperature increments of the order of 6° C, from an initial temperature of 30° C, do not involve the loss of fluid in the form of steam provided that the depth of water is greater than the diameter of the container. Therefore, the calorimeter should be so designed that its cross-sectional area is as small as possible and the depth of water as large as possible to give the maximum rate of cooling of the hot specimen by convective heat transfer.

APPENDIX II

The Heater for Calorimeter Calibration

The electrical input to a heater R_1 is measured by precision potentiometers connected across a divider resistance in parallel with the heater and across a known resistance in series with the heater. The arrangement is illustrated in Fig. 5 where the heater is represented by a resistance R_1, the divider by a resistance R_2, and R_3 is the series resistor. The currents and voltages are as indicated in the diagram and the following equations apply.

$$V_1 = d.V_2 \text{ where } d \text{ is the divider ratio for the resistance } R_2$$

$$\text{and } I_1 = \frac{V_3}{R_3} - I_2$$

$$= \frac{V_3}{R_3} - \frac{V_1}{R_2} \quad \text{Hence } I_1V_1 = d.V_2\left\{\frac{V_3}{R_3} - \frac{d.V_2}{R_2}\right\}$$

The following values were used:

R_2 50,000Ω
d 999·05
R_3 0·0992Ω

$$\text{Hence } I_1V_1 = 10{,}071\left(V_3 - \frac{V_2}{504}\right)V_2 \text{ watts}$$

and the total energy added in time θ is given by

$$10{,}071\left(V_3 - \frac{V_2}{504}\right)V_2.\theta \text{ joules.}$$

Typical values for V_2 and V_3 were 203·91 mV and 176·22 mV. θ was assigned values from 60 s to 140 s. The voltages could be measured to ± 0·002 mV but a slow fluctuation of the values during a run limited the mean values for V_2 and V_3 to an accuracy of ± 0·03 mV. θ was measured to an accuracy of 0·02 s, and to facilitate the synchronism between the starting and stopping of the heater current and the chronometer, the switching was so arranged that the same movements were required for either operation. Thus $I_1V_1\theta$ may be evaluated to an estimated accuracy better than ± 0·1%.

APPENDIX III

The Transition Points of Pure Iron

Since the early study of the allotropic forms of iron by Osmond[22] the existence and significance of the A_2, A_3 and A_4 points has become established. The temperatures at which these transitions occur have been subject to considerable investigation, but some lack of reproducibility in the results has been shown. Other transitions have been reported from discontinuities in the thermal properties of pure iron but the source of these has been indicated by Pilling,[23] Jaquerod and Gagnebin,[24] and Jaeger, Rosenbohm, and Zuithoff[25] as the varying emission rates of occluded gases.

The A_2 point, marking the change from α- to β-iron, is not a true transformation point, since α- and β-iron have the same allotropic form, but corresponds to the Curie point where the intermolecular changes related to the loss of ferromagnetism are complete. It is therefore a transition point separating the ferromagnetic and paramagnetic forms of iron. The A_2 point temperatures obtained by selected observers are given in Table V in historic sequence. The general state of purity of the samples has been taken into account in the selection, but the purity reported is not tabulated since this can often lead to erroneous conclusions when different samples are compared. The carbon content tests for instance have been subject to considerable revaluation recently and many differences in reported carbon contents may be due to differing analytical methods. Again, the analyses are seldom complete and the influences of undetected impurities on the thermal properties of pure iron may be considerable. Dilatometric, electrical resistance, and thermo-electric methods have been rejected since they are not directly relevant. Since the A_2 point is the Curie point, magnetometric methods for its determination are included. In ordinary calorimetry the number of measurements taken is usually insufficient to locate a transition point accurately; but with an adiabatic calorimeter continuous temperature ranges may be explored and this method can be used to establish transition temperatures.

Table V

A_2 TRANSITION IN PURE IRON

Observer	Method of Determination	Temperature of A_2 Transition, °C
Ruer and Goerens[26]	Thermal analysis	769
Tritton and Hanson[27]	Thermal analysis	763
Ruer and Bode[28]	Thermal analysis	769
Ruer and Bode[28]	Magnetometric analysis	769
Wever[29]	Thermal analysis	768
Klinkhardt[30]	Adiabatic calorimetry	760
Regner[31]	Magnetometric analysis	765
Adcock[32]	Thermal analysis	767
Adcock[32]	Magnetometric analysis	774
Esser and Cornelius[33]	Thermal analysis	775
Lapp[34]	Adiabatic calorimetry	758
Awbery and Griffiths[18]	Adiabatic calorimetry	755

Little hysteresis has been observed in the A_2 point so that where the temperature of transition measured with increasing temperatures differs slightly from that measured with decreasing temperatures the mean of the two measurements has been tabulated.

From the table, magnetic and thermal analyses give a range of 763–775° C for A_2 whereas adiabatic calorimetry gives 755–760° C. If it is assumed that the enthalpy of α-iron is a cubic function of temperature and the enthalpy of β-iron is a linear function of temperature, then the greatest rate of change in the value of the specific heat, which is the differential of enthalpy, will occur at the transition point. The determination of specific heats by adiabatic calorimetry should therefore lead to the same value for the temperature at which the maximum rate of change of specific heat occurs as found for the Curie point by other methods. Awbery and Griffiths[18] suggested that a reduction of the Curie temperature resulting from greater purity would explain their low value. This is not confirmed by the low value for A_2 obtained by Jenkins, Bucknall, and Jenkins[35] using various carbon steels.

Both the sets of tabulated values obtained by magnetometric and thermal analysis have a mean value of 769° C, and a symmetrical frequency distribution about this mean. The best value for A_2 is therefore taken to be 769° C.

Table VI gives selected values for the A_3 point, at which a true transformation from β- to γ-iron occurs. Here again indirect measurements by electrical resistance and thermoelectric methods have not been included; and since the transition is not a magnetic one, magnetic methods have also been excluded. Since the A_3 transformation involves a change of crystal structure, dilatometric methods of detecting the temperature of the transformation are not indirect in this case.

Table VI

A_3 TRANSFORMATION IN PURE IRON

Observer	Method of Determination	Temperature of Transformation, °C	
		Ac_3	Ar_3
Burgess and Crowe[36]	Thermal Analysis	909	898
Ruer and Goerens[26]	Thermal Analysis	—	900
Souder and Hidnert[37]	Dilatometry	912	906
Tritton and Hanson[27]	Thermal Analysis	912	885
Wever[29]	Thermal Analysis	—	906
Klinkhardt[30]	Adiabatic Calorimetry	911	—
Esser[38]	Dilatometry	905	900
Satô[39]	Dilatometry	903	903
Harrington and Wood[40]	Thermal Analysis	910	902
Adcock[32]	Thermal Analysis	918	902
Adcock[32]	Dilatometry	917	900
Hensel and Larsen[41]	Dilatometry	930	918
Esser and Cornelius[33]	Thermal Analysis	923	905
Austin and Pierce[42]	Dilatometry	929	927
Wells, Ackley and Mehl[43]	Dilatometry	910	910
Wells, Ackley and Mehl[43]	Thermal Analysis	910	910
Lapp[34]	Adiabatic Calorimetry	910	—
Awbery and Griffiths[18]	Adiabatic Calorimetry	903	—
Cleaves and Hiegel[44]	Thermal Analysis	910	900

Table VII

A_4 TRANSFORMATION IN PURE IRON

Observer	Method of Determination	Temperature of Transformation, C	
		A_{c_4}	A_{r_4}
Ruer and Goerens[26]	Thermal Analysis	1403*	
Hanson and Freeman[49]	,, ,,	1401*	
Tritton and Hanson[27]	,, ,,	—	1403*
Vogel[50]	,, ,,	1395	
Sykes[51]	,, ,,	—	1401*
Satô[39]	Dilatometry	1400	1400
Wever[29]	Thermal Analysis	1401	
Kasé[52]	,, ,,	1410	
Andrew and Binnie[53]	,, ,,	1401*	
Bennek and Schafmeister[54]	,, ,,	1410	
Adcock[32]	,, ,,	1396*	1395*
Adcock[55]	,, ,,	1383*	1382*
Bristow[56]	,, ,,	1388*	1385*

* Figures corrected to the International Temperature Scale of 1948

Some of the tabulated results show a definite difference between Ac_3, the transformation temperature obtained when the exploration is carried out with increasing temperature, and Ar_3, the transformation temperature obtained when a falling temperature exploration is made. This difference was shown by Burgess and Crowe[36, 45] to depend to some extent on the rate of change of temperature, which affected the value of Ar_3 more than Ac_3. They used a range of different rates of heating or cooling for a thermal analysis, and the results tabulated were obtained by extrapolation to a zero rate. Satô[39] showed the same dependence of A_2 on the rate of change of temperature using a dilatometer and found the values of Ac_3 and Ar_3 equal when the extrapolation to a zero rate was made. Wells, Ackley, and Mehl[43] confirmed these reports for both thermal analysis and dilatometry, obtaining a value of 909·5° C for Ac_3 and Ar_3 at zero rate of change of temperature with both methods.

The A_3 transformation was only completed over a temperature range of 20–25° C, when Satô's[46] first dilatometer experiments were carried out and Honda and Miura[47] found a range of 40–45° C. This may be due to temperature gradients in the specimen and the range was reduced to 10° C in Satô's later and improved measurements which are tabulated. Satô took the lowest temperature of the range for the A_3 value, but 908° C the mean value of the range is in better agreement with the value given by Wells *et al.*

Harrington and Wood[40] found double transformation effects separated by as much as 45° C for both Ac_3 and Ar_3 and in a later paper[48] they gave a theoretical explanation for double transformations. However, Esser and Cornelius[33] showed that the appearance of double A_3 transformations could be produced in a thermal analysis by annealing in hydrogen. Therefore, the values tabulated above for Harrington and Wood are those corresponding to the most marked of each of the double transformation temperatures.

Since Ac_3 is less affected by the rate of change of temperature than Ar_3 and since there are indications that Ac_3 and Ar_3 have equal values at an infinitely slow rate of

Table VIII
FREEZING POINT OF PURE IRON

Observer	Method of Thermal Analysis	Freezing Point, °C
Ruer and Klesper[57]	Thermocouple	1531*
Burgess and Waltenberg[58]	,,	1535*
Burgess and Waltenberg[58]	Optical Pyrometer	1533*
Hanson and Freeman[49]	Thermocouple	1531*
Tritton and Hanson[27]	,,	1532*
Vogel[50]	,,	1530*
Sykes[51]	Optical Pyrometer	1533*
Kasé[52]	Thermocouple	1530
Andrew and Binnie[53]	,,	1534*
Jenkins and Gayler[59]	Optical Pyrometer	1527
Bennek and Schafmeister[54]	Thermocouple	1530
Adcock[32]	Optical Pyrometer	1524*
Adcock[32]	Thermocouple	1525*
Adcock[55]	,,	1530*
Bristow[56]	,,	1531*
Chipman and Marshall[60]	,,	1532*
Cleaves and Hiegel[44]	Optical Pyrometer	1535*
Schofield and Bacon[61]	,,	1535*

* Figures corrected to the International Temperature Scale of 1948

temperature change, the Ac_3 values in the table are taken to be more representative of the A_3 transformation than the Ar_3 values. A frequency curve of the Ac_3 values shows over half of the total in the temperature range 909–912° C, while the remainder are spread into four small separate groups. The mean of the values in the dominant group is 910° C, which is taken to be the best value for A_3.

In drawing up a table of selected values for the A_4 point, at which γ-iron changes to δ-iron, the direct methods of thermal analysis or dilatometry have again been chosen. At this point no data obtained by adiabatic calorimetry have been published.

All the temperature measurements so far tabulated have been based on a temperature scale in which the gold point at 1063° C is a primary fixed point. The temperatures are therefore correct with reference to the International Temperature Scale of 1948. At temperatures above the freezing point of gold, where nickel or palladium points have been used to define the thermocouple temperature scale, the data given for the A_4 or freezing points of iron have been corrected to the International Temperature Scale of 1948. Some authors do not give enough information for this correction, which is not usually greater than 3° C, to be made. The corrected figures have therefore been marked with an asterisk.

There is little evidence of a definite hysteresis in the A_4 transformation and the high rate of reaction to be expected at high temperature would make this unlikely. If the corrected temperatures only are taken, if the later value given by Adcock is assumed to supersede the first one, and where two values are quoted the Ac_4 value is used, a mean value of 1397° C is obtained for A_4. However, five of the seven figures used to give this mean, lie in the range 1401–1403° C so that it is suggested that 1401° C is a more acceptable figure for A_4.

Table VIII gives selected values for the freezing temperature of pure iron. Where sufficient information is available, the published figures have been converted to the International Temperature Scale of 1948, by correction of the reference points for the immersed thermocouple method and correction of the C_2 constant in Planck's formula for optical pyrometer determinations.

Twelve of the 14 corrected values tabulated in Table VIII lie in the range 1530–1535° C and the other two values, occurring at 1524° and 1525°, were obtained by Adcock who published a figure of 1530° C after subsequent investigations. It would appear to be reasonable to accept only the twelve closely grouped values which yield a mean value of 1532·7° C. A greater weight could be attached to the value obtained by Burgess and Waltenberg, which is a mean value of careful determinations of the freezing point of five different samples of iron (1536, 1534, 1535, 1536, and 1534° C)* by means of a thermocouple. Inclusion of these results, instead of the mean value of 1535° C, leads to a value of 1533·3° C for the mean of 16 figures. In the circumstances a figure of 1533° C is indicated for the freezing point of iron.

To summarize, a survey of the published figures for the transition points of pure iron leads to the following selected values:

A_2 point	769° C
A_3 point	910° C
A_4 point	1401° C
Freezing point	1533° C

APPENDIX IV
The Enthalpy of Platinum

The enthalpy of pure platinum has been measured over various temperature ranges by a number of observers, but the work of Wüst, Meuthen, and Durrer[13] and Jaeger and Rosenbohm[62] appears to be the most reliable, as well as the latest.

Wüst *et al.* used an electric vacuum furnace combined with a Bunsen ice calorimeter, suspending the specimens in fused silica capsules. The specimen temperatures were measured by thermocouples in a sheath placed alongside the specimen and the thermocouples were calibrated against the primary silver and gold points and the secondary tin, lead, zinc, antimony, and nickel points. The greatest differences between the fixed temperatures used and those adopted in the 1948 International Temperature Scale occur for gold (1064° C instead of 1063° C) and nickel (1451° C instead of 1453° C).

Table IX
ENTHALPY OF PLATINUM VALUES

Temperature, °C	Enthalpy of Pure Platinum, cal/g			
	Data from Wüst uncorrected	Data from Jaeger corrected to 1552° C, palladium point	Mean of Wüst and Jaeger's data	From the equation fitted to the mean values
0	0	0	0	0
100	3·16	3·19	3·175	3·17
200	6·38	6·44	6·41	6·41
300	9·68	9·77	9·725	9·71
400	13·05	13·15	13·10	13·08
500	16·49	16·60	16·545	16·53
600	20·00	20·11	20·055	20·04
700	23·58	23·68	23·63	23·61
800	27·23	27·32	27·275	27·26
900	30·96	31·02	30·99	30·98
1000	34·75	34·79	34·77	34·76
1100	38·61	38·62	38·615	38·61
1200	42·55	42·52	42·535	42·53
1300	46·56	46·48	46·52	46·52
1400	50·63	50·51	50·57	50·58
1500	54·78	54·60	54·69	54·71

Table X
ENTHALPY OF ALUMINA

Temp, °C	Enthalpy A_0^T cal/g from the following sources:						
	Esser[71]	Ginnings[66]	von Gronow[73]	Roth[64]	Shomate[76]	Wilkes[77]	Authors
900	226·17	238·75	236·70	233·96	237·94	229·86	245·53
1000	255·00				268·03		276·14
1100	286·11		296·01		298·12	288·42	306·75
1200	320·52				328·21		337·36
1300			357·24		358·30	348·94	367·97
1400					388·39		398·58
1500			419·40		418·48	410·39	429·19
1600					448·56		459·80
	Mean specific heat over temperature ranges above						
	0·315		0·305		0·301	0·301	0·306

Jaeger and Rosenbohm used a metal block calorimeter and suspended the specimen inside the furnace with a thermocouple inserted into a vertical hole in the specimen. Details of the calibration of this couple were not given in the original paper but in a later publication[63] the enthalpy results were corrected for a palladium point of 1555° C instead of 1549° C as originally used.

Table IX gives values of the enthalpy of platinum at 100° C intervals obtained from the smoothed curves of the two sets of observers. The values due to Wüst are uncorrected for the variation from the 1948 International Temperature Scale, but the two sets of data published by Jaeger have been used to derive values corrected to a palladium point of 1552° C as adopted in this scale. Wüst's results refer directly to zero enthalpy at 0° C and Jaeger's have been converted to zero reference at 0° C by extrapolation from the actual temperatures used in the block calorimeter.

The differences between the results of Jaeger and those of Wüst are less than 1% over the whole range of temperature. The third column of enthalpies in Table IX consists of mean values of the two preceding columns giving equal weight to the two different observers. These mean values have been used to derive the following equation for the enthalpy P_0^T at a temperature T °C with respect to zero enthalpy at 0° C:

$$P_0^T = 0{\cdot}0342\left(\frac{T}{100}\right)^2 + 3{\cdot}134\left(\frac{T}{100}\right)$$

The fourth column of enthalpies in the table was obtained from this equation, and they agree within 0·2% with the mean values in the third column.

APPENDIX V

The Enthalpy of Alumina Between 0° and 100° C

A considerable number of determinations of the enthalpy of alumina over various temperature ranges have been published but few of these include measurements between 0° and 100° C. Roth and Bertram[64] made one measurement at 96° C, Tscherboff and Tschernjak[65] made one measurement at 50° C and one at 100° C, and Ginnings and Corruccini[66] made three measurements at 50·3° C.

However, Parks and Kelley[67] measured the true specific heat of alumina at a number of low temperatures including 1·9, 3·2, 15·4, and 18·1° C. If the relation between true specific heat and temperature is assumed to be linear, a regression line for the four measurements may be computed. Integration of the equation of this line leads to the equation

$$A_0^t = 17{\cdot}21\left(\frac{t}{100}\right) + 2{\cdot}60\left(\frac{t}{100}\right)^2$$

where A_0^t is the enthalpy of alumina in cal/g at t° C with respect to zero at 0° C.

At 100° C this equation gives a value of 19·81 cal/g for A_0^t which is smaller than the smoothed values of 20·03 and 20·04 given by Tscherboff and Tschernjak, and Roth and Bertram, respectively, but larger than the smoothed value of 19·58 given by Ginnings and Corruccini. The difference in each case is about 1·2%. Between 20° and 60° C the values given by the equation are within 0·3% of the smoothed values given by Ginnings and Corruccini.

Probably the equation represents as good a compromise between the different sets of published data as possible.

APPENDIX VI

The Enthalpy of Alumina Between 900° C and 1600° C

The enthalpy of alumina has been measured at temperatures in the 900–1600° C range by Auzhbikovich,[68] Cohn,[69] Cohn and Magee,[70] Esser, Averdieck, and Grass,[71] Ginnings and Corruccini,[66] von Gronow and Schwiete,[72] Laschschenko and Kompanskii,[73] Lyaschenko,[74] Miehr, Immke, and Kratzert,[75] Roth and Bertram,[64] Shomate and Naylor,[76] von Wartenberg and Witzel,[77] and Wilkes.[78] Little weight can be attached to the data published by over half these investigators but the smoothed values for enthalpy obtained by the others are given in Table X, together with the values obtained from the equation $A_0^T = 30{\cdot}610\left(\frac{T}{100}\right) - 29{\cdot}96$ derived in an earlier section of this report.

The differences between the sets of data are too large to be accounted for solely by the heat loss from the specimen during descent from the furnace. The purity of the sample may have some influence. Synthetic corundum (α-Al_2O_3) was used by all the investigators with the exception of Shomate and Naylor who used crushed natural sapphires. Only Ginnings and Corruccini gave an estimate of the purity of their sample (99·97%) which compares with the 99·7% purity of the crucible material used in the work being described. However, the main source of the differences probably lies in unknown experimental errors. See, for instance, the differences between the results of Esser, Averdieck, and Grass and von Gronow and Schwiete which were all obtained with metal block calorimeters. The mean specific heats differ less than the enthalpies.

APPENDIX VII

The Enthalpy of Pure Iron Between 0° and 100° C

In a previous report[1] the published work on the enthalpy of pure iron was reviewed. Only one direct investigation of enthalpy, carried out by Oberhoffer and Grosse,[16] included measurements between 0° and 100° C. However, Griffiths and Griffiths[79, 80] carried out very accurate direct measurements of true specific heats over this temperature range. Integration of their equation for specific heat yields the equation

$$I_0^t = 10{\cdot}45\left(\frac{t}{100}\right) + 0{\cdot}7942\left(\frac{t}{100}\right)^2 - 0{\cdot}2149\left(\frac{t}{100}\right)^3$$

for the enthalpy I_0^t of iron at t° C. Substitution in this equation gives values for I_0^t at the temperatures 97·61, 98·00, and 98·56° C, investigated by Oberhoffer and Grosse which differ from the latter's values by less than 1·4%. Since more weight may be attached to the Griffiths and Griffiths measurements the values of enthalpy given by the equation are probably reliable to 1%.

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OBITUARY

James Spencer Hollings, C.B.E.

Mr. James Spencer Hollings, who was born in 1872 and educated at Sedbergh, died on 21st June, 1956. He was initially trained as a mining engineer, but entered the steel industry in 1893 under J. H. Darby of the Brymbo Steel Co., Ltd., where the basic open-hearth process was first successfully operated in this country. Mr. Hollings was associated with this company for over thirty years and was appointed Managing Director in 1914. During this period he travelled extensively in connection with the many developments then taking place in the iron and steel industry, and thus built up a very comprehensive knowledge of the industry abroad, more particularly in Germany and the United States of America.

After the Brymbo Steel Co., Ltd., was absorbed by Baldwins, Ltd., he served under another notable pioneer, Sir John Roper Wright, who was associated with Sir William Siemens when the acid open-hearth method of steelmaking was developed. Subsequently, Mr. Hollings served under Sir John Roper Wright's successor, Sir Charles Wright, and later was appointed Managing Director and Vice-Chairman of Guest Keen Baldwins Iron and Steel Co., Ltd. (now Guest Keen Iron and Steel Co., Ltd.). He retired from these positions in 1945, in order to leave the way clear for younger men, but retained his seat on the Board. During the war his advice was sought by the Ministry of Home Security and his services were recognized by the award of the C.B.E.

Although an acknowledged expert on blast-furnace and coke-oven practice, some of his most notable contributions to the industry have been in the field of design and layout of integrated plant. In the period 1928–1929 he was associated with the design of the works of the South African Iron and Steel Industrial Corporation Ltd., and some seven years later he was responsible for the planning of the East Moors Works of Guest Keen Baldwins Iron and Steel Co., Ltd.

Among other activities, Mr. Hollings was a Director of Tarmac (S. Wales) Ltd., the Briton Ferry Ironworks, Ltd., the Oxfordshire Ironstone Co., Ltd., Minera Lime Co., Ltd., and had been Chairman of Sinai Mining Co., Ltd., and of Tonfanau Granite Quarries, Ltd.

He served on the executive committee of the Iron and Steel Federation for several years and on the Council of The British Iron and Steel Research Association. In addition, he was Chairman of the National Association of Hematite Pig Iron Manufacturers for over ten years, and was Chairman of the Basic Pig Iron Producers Association for approximately seven years.

He became a Member of The Iron and Steel Institute in 1903, was elected a Member of Council in 1930, Vice-President in 1938, an Honorary Vice-President in 1946, and an Honorary Member last March. He was awarded the Bessemer Gold Medal in 1946 " in recognition of his distinguished services in encouraging technical improvement in the manufacture of iron and steel."

Mr. Hollings enjoyed many and varied hobbies and interests. He was a cricketer of some distinction, playing in Minor County cricket for some years. He was a gardener of great knowledge and had a deep interest in furniture, china, and glass. During his long life, he met many people in all walks of life and none left him without being impressed by his ability, the breadth of his knowledge, and his kindliness.

In 1906, he married Mary Dudley, daughter of the late Francis Arber Brown, who died in 1949. There was one son of the marriage.

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(*continued from p.* 348)

was " Fracture in Metals," and the text was published in the July, 1956, issue of the *Journal*.

A vote of thanks to Professor Mott, proposed by the President, and seconded by Mr. D. A. Oliver, C.B.E., was carried unanimously.

MEMBERS' DINNER

The Annual Dinner was held at Grosvenor House, Park Lane, London, W.1, on Wednesday, 16th May, 1956. The toast of " The Iron and Steel Institute and Industry " was proposed by Lieut.-General Sir Ronald Weeks, K.C.B., C.B.E., D.S.O., M.C., T.D., and replied to by the President, Dr. H. H. Burton, C.B.E. Mr. R. Mather (Past-President) proposed the toast of " The Guests," to which Dr. J. M. Whittaker, F.R.S., replied.

PRESENTATION OF PAPERS

A list of the papers presented and discussed at the Technical Sessions of the Annual General Meeting appeared on p. 396 of the April, 1956, issue of the *Journal*. Reports of the discussions will be published later in the year.

A Laboratory Study of the Sintering Process

By E. W. Voice and R. Wild

SYNOPSIS

A laboratory technique has been devised for studying fundamental sintering problems. Initial trials showed that, using similar mixes and airflows to those employed in practice, normal sinter could be produced. Bed temperature and pressure distribution, flame front travel, and air and heat requirements can all be studied effectively on this scale and valuable data obtained. 1279

THE SINTERING PROCESS can be studied by observing the effects of known variations in the feed and operating conditions of a sinter plant and valuable results have been obtained from such studies.[1,2] Investigations of this nature require large-scale instrumentation and the extent to which normal sintering practice may be varied is limited. It is, however, possible to isolate a section of the bed and use it to study the sintering process without encountering the difficulties inherent in scaled-down experiments, since the size and composition of the sinter mix and the air flow (ft^3/min per ft^2 of bed surface) can be kept the same as in normal practice, and the material is subjected to a similar sequence of operations as it would in full-scale operation. Various investigators have used a single pallet, a 2-ft square box,[3] a 14-in. square box,[4] a 1-ft square box,[5] and a 4-in. dia. cylinder.[6]

The 2-ft square sinter box used by B.I.S.R.A. has proved of great value for studying the particular problems involved in sintering various ore mixtures, etc., and valuable basic knowledge has been derived from these results. Work on this scale, however, still involves handling considerable quantities of materials (about 500 lb of ore and 400–500 ft^3/min air), and is thus unsuitable for general use in the laboratory. With this 2-ft square sinter box, the quantity of unsintered material left at the walls is very small, suggesting that a much smaller container could be used with safety, provided that abnormally large pieces are excluded from the sinter mix, and materials giving rise to excessive shrinkage are avoided. After considering all the factors involved, it was decided that a 3-in. dia. sintering pan would be suitable for use in a research laboratory. On this scale only 2 or 3 lb of material are used as charge; this enables a considerable number of experiments to be carried out on the same batch of material and the same stock of coke can be used for a complete range of experiments. The air volume used for a single experiment (about 30 ft^3) is sufficiently small for the use of oxygenated air to be a practical possibility.

The full-scale research work on operating sinter plants combined with trials made in the 2-ft square sinter box have enabled empirical formulæ to be derived, from which a sinter plant may be designed to give a definite output. The theoretical basis for these formulæ, however, is not yet fully understood. The contribution by Wendeborn to the recent sinter symposium[7] suggested that more knowledge of the fundamental factors involved in sintering might enable these empirical formulæ to be placed on a firm basis. In particular, a better understanding is necessary of the factors governing the quantity of air needed for sintering.

For these reasons, a laboratory sinter pan has been installed to assess its reliability as a method of studying the sintering process, and to apply it to elucidate the fundamental factors which control the process.

DESCRIPTION OF APPARATUS AND EXPERIMENTAL PROCEDURE

The layout of the apparatus is shown in Fig. 1. The sinter pan consists of a 3-in. inside diameter steel tube which fits into a base containing a steel mesh grate with $\frac{1}{8}$-in. apertures above a simple wind box. Holes are drilled to enable bed temperatures and suctions to be measured at the desired positions, and provision is made for the suction, temperature, and gas composition in the wind box to be measured. The base is connected to a cooling coil and from this to a venturi and a fan. The air flow is regulated by controlling the quantity of air bled into the fan. During sintering, the sinter pan is lagged with a layer of insulating material.

The raw mix is tumbled in a rotating drum to ensure complete mixing. A hearth layer is loaded on to the grate and then the raw mix is charged by hand to the desired depth, bed thermocouples and suction probes being inserted as required during filling.

Any normal type of ignition, such as gas or oil, can be used but it was decided to use a heated refractory block slotted so that the air may be drawn through it. It is now realized that this is probably not the best method of ignition, but it does allow

Paper IM/AA/56/55 of the Sintering Sub-Committee of the Ironmaking Division of the British Iron and Steel Research Association, received on 14th February, 1956. The views expressed are the authors', and are not necessarily endorsed by the Committee as a body.

Mr. Voice and Dr. Wild are with the Ironmaking Division of B.I.S.R.A.

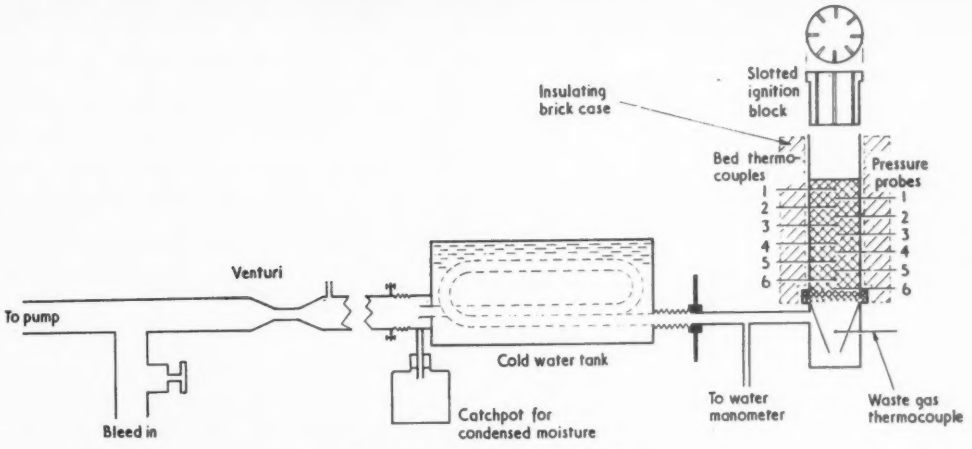

Fig. 1—Lay-out of apparatus

standard, reproducible ignition conditions to be obtained. The dimensions of this block are such that, when it is in the ignition position, there is a $\frac{1}{8}$-in. gap between it and the top of the bed. Sintering is commenced by inserting the block, previously heated to 1320° C, into the sinter pan, starting the fan, and adjusting the air flow to the desired volume, normally 6 ft³/min. After ignition (which varies from 30 to 60 s) the block is removed and the air flow re-set to 6 ft³/min. From now onwards the suction is maintained constant until peak waste gas temperature has been reached. Air flow, suction, exit gas temperature, and temperatures and suctions at suitable points in the bed are all recorded throughout the experiment.

Initial Experiments with Iron Ores

A variety of mixes were made from magnetite, hard and soft hematites, and lean home ores, and sintered in the normal manner. Figure 2 shows a sinter cake made from magnetite ore. The sinters made are very similar in texture to those made commercially and the extremes of sinter quality encountered on sinter plants have been obtained in the small sinter pan, as may be seen from Fig. 3. The quantity of unsintered material at the periphery of the cake is small under normal sintering conditions, and the temperature distribution within the bed is similar to that obtained in normal practice. The average permeability during sintering varied from 70 to 150 B.P.U's, and the quantity of exit gases when sintering a ton of raw mix varied from 24,000

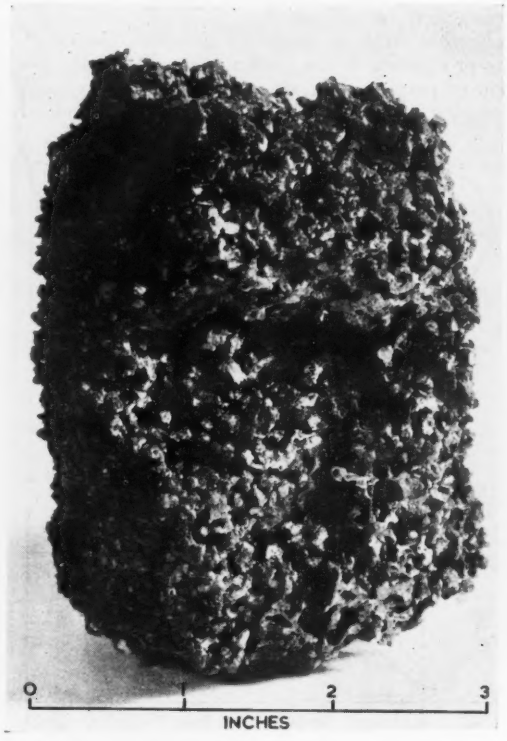

Fig. 2—Sinter cake from laboratory sintering unit

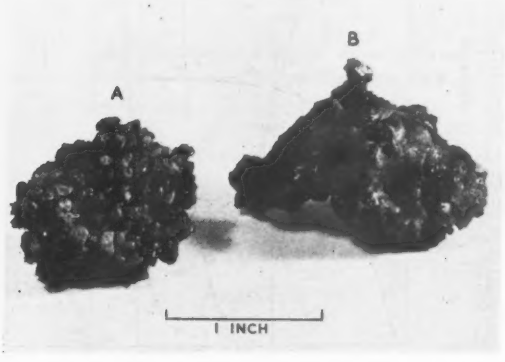

Fig. 3—Extremes of sinter from laboratory unit: (*a*) friable, (*b*) overburnt

Table I

RATES OF HEATING AND COOLING AT BOTTOM OF BED

Substance	Rate of Heating, °C/s	Rate of Cooling, °C/s	Bulk Density, lb/ft³
Alumino-silicate brick	200	16	25·5
Silica	80	7·5	66
Mullite	60	4·5	81
Alumina	40	2·25	117

to 50,000 ft³, values which are comparable with full-scale practice.

Experiments with Inert Materials

Iron-ore sintering is a very complex process. Air is drawn through a bed of materials varying from ½-in. lumps down to dust; heat must be transferred down the bed to effect combustion of coke; water evaporation, carbonate calcination, oxidation, and reduction of iron oxides are all proceeding, and agglomeration of the charge takes place with or without partial slagging. All these phenomena take place either simultaneously or in sequence; thus it is very difficult to study the influence of any one on the whole process. By using inert material graded within narrow limits (normally $\frac{1}{16}$–$\frac{1}{8}$ in.) it is possible greatly to simplify the whole process. Oxide changes, agglomeration, and slagging can be eliminated and the essential phenomena associated with the passage of a combustion front through a bed of granular materials may be studied. Although agglomeration does not normally take place, the process is referred to, for convenience, as sintering. By a suitable choice of material, the water content of the sinter mix may be varied over a wide range, thus enabling its influence on the sintering process to be assessed. Calcium carbonate may be used alone or admixed with inert material, so that the influence of an endothermic reaction at high temperature can be studied.

From the measurements taken during the experiment, the bed temperature and pressure distribution were obtained and the speed at which the flame front travelled through the bed. The permeability of the bed[8] at different stages in the sintering process has been calculated using the formula

$$P = \frac{F}{A}\left(\frac{h}{s}\right)^{0.6}$$

where P = permeability (B.P.U's.), F = volume flow (ft³/min at 30 in. Hg and 60° F), A = area (ft²), h = bed height (in.) and s = suction (in. w.g.). Whilst this formula may not be correct in respect to the power of h and s for these particular bed materials, it is used for the present as the best available. The volumes of intake air and exit gases up to the moment when the waste gas temperature reaches the peak value have been calculated, the former by subtracting the volume of CO_2 from calcination from the measured waste gas volume, and the latter by adding the volume of water vapour condensed in the cooling coil to the measured volume. A knowledge of the coke used and the water and marble content of the beds enabled the net heat available to be calculated.

Further work is envisaged in which the effect of the production of low melting compounds, the variation of particle size, air preheat, oxygen content of sintering ' air,' and other variables will be studied.

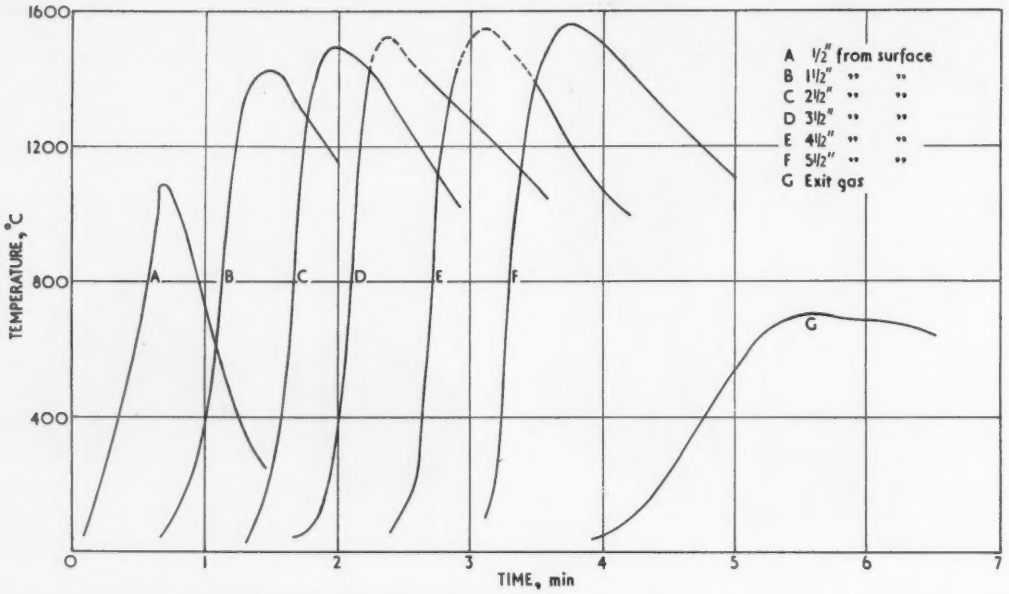

Fig. 4—Temperature distribution at each level in the bed

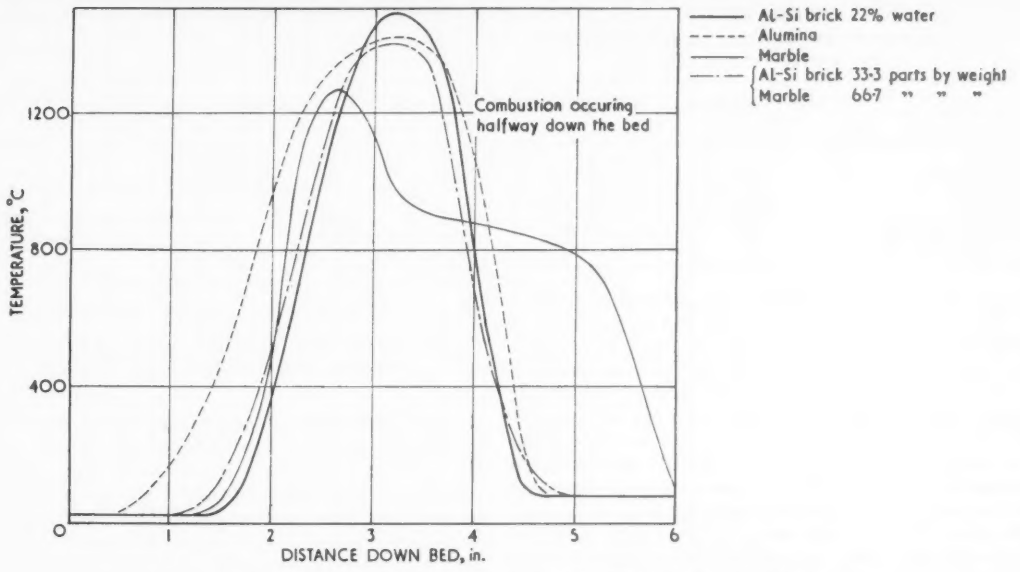

Fig. 5—Temperature distribution for different sinter mixes

PRELIMINARY RESULTS

Temperature Distribution within the Bed—The manner in which the temperature changes with time at various levels within a bed of silica (quartz) chips is shown in Fig. 4. The rate of rise is very high (about 80° C/s) at all levels, whereas the rate of fall is always lower, becoming increasingly so towards the bottom of the bed. The rates of rise and of fall of temperature vary with differing bed materials as may be seen in Table I which shows the rates of heating and cooling at the bottom of the bed. This table also shows that these values vary inversely as the bulk density of the bed material.

The temperature distribution within the bed when the combustion zone is about halfway down is shown in Fig. 5 for a number of bed materials. The temperature distribution is, in general, very similar in all cases, except for a bed consisting entirely of marble. In this case the endothermic calcination reaction cannot be completed in advance of the combustion front, and thus the temperature is limited to about 900° C until calcination is complete, after which combustion of the residual coke raises the temperature to a higher level. This is a definite example of the phenomenon cited by Wendeborn[7] in his theoretical approach to the problem where he stated " When carrying out endothermic reactions, such as the decomposition of carbonate, the vertical speed of propagation of the heat consuming reaction must be greater than that of the exothermic. With this condition reversed, no temperature higher than the decomposition temperature of the endothermic substance (e.g. 900° C with lime) can be attained."

Flame Front Speeds—Whilst the term ' flame front

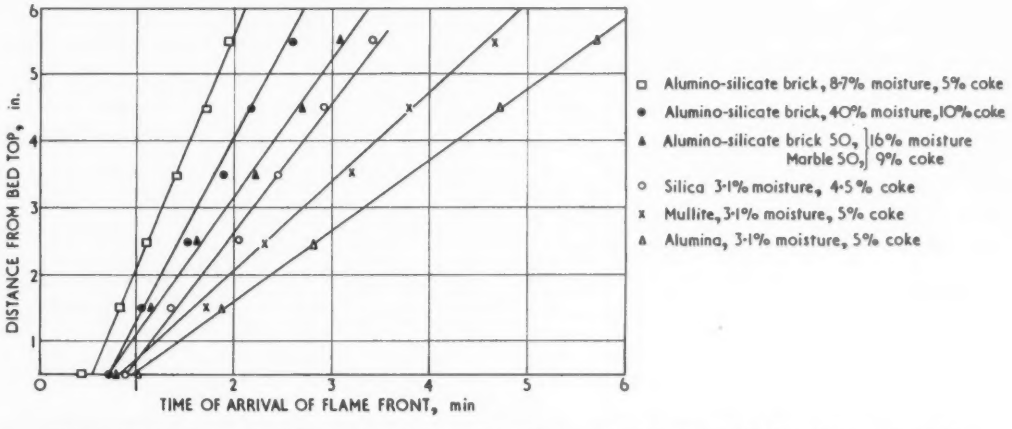

Fig. 6—Rate of travel of flame front through various materials (normal sintering conditions)

Table II
RELATIONSHIP OF FLAME FRONT SPEEDS AND BULK DENSITIES

Substance	Flame Front Speed, in./min	Bulk Density, lb/ft³
Alumina	1·0	117
Mullite	1·3	81
Silica	1·9	66
Porous alumino-silicate brick	3·0	25·5

speed ' has often been used, it has never been defined in the literature. In this work the flame front is defined as the level at which the most rapid temperature rise is occurring, and thus the flame front speed is the rate of travel through the bed of this front. Figure 6 shows the rate of travel of the flame front for various bed materials, the initial air flow being the same in each case and constant suction being maintained. For each material, normal sintering temperature conditions have been established, which, for this work, are defined as a maximum temperature of 1450–1500° C halfway down the bed and 1550–1600° C at the bottom. The coke content in these experiments varied from 4·5% to 10%. It can be seen that under these conditions the flame front moves down the bed at a uniform speed. Table II shows that the flame front speeds are inversely related to the bulk densities of the materials.

Pressure Drop in the Bed—The change in pressure from the top to the bottom of the bed when combustion is taking place halfway down is shown in Fig. 7. Figure 8 shows the way in which the maximum resistance to flow is always located in the region of the highest temperature. The pressure drop through the bed is not uniform during sintering; the pressure drop per unit height is greatest, and hence the permeability in B.P.U's. is least, in the high-temperature zone. The converse is true in the zone where combustion has been completed and the material is partially cooled. It should be remembered that the permeability is not corrected for temperature, and thus it is to be expected that the minimum permeability is in the hottest zone.

Bed Permeability—During sintering, the permeability of the bed normally falls to a minimum value

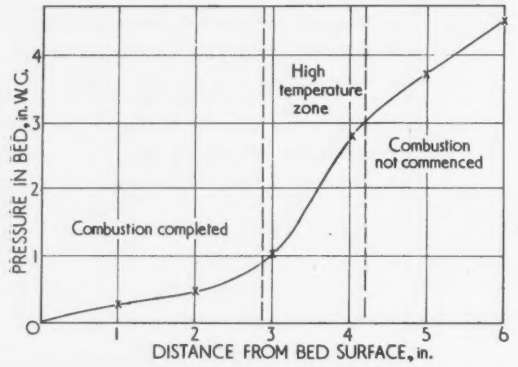

Fig. 7—Pressure distribution down bed

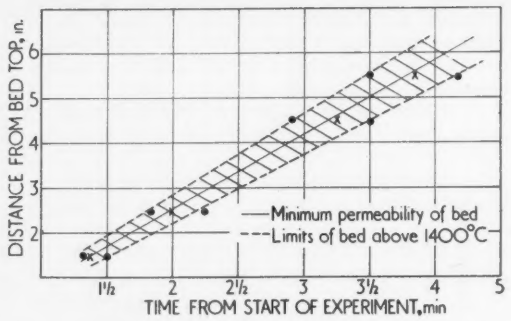

Fig. 8—Relationship between regions of highest temperature and maximum bed resistance

(trough permeability) and then rises again. Some materials, however, do not behave in this way, and the permeability rises throughout the sintering process. The changes in permeability during sintering are illustrated in Fig. 9 where air flow during sintering is plotted against time. Since suction, bed height, and area are constant throughout each experiment, air flow is proportional to permeability. Rising permeability has only been found with porous materials which need a high moisture content to give the correct bed texture. Water content has a large influence on the bed permeability at all stages of sintering as may be seen in Table III, which shows the permeability of porous alumino-silicate brick with a wide range of water contents. With this material, permeability rises to a maximum at 32% water content, thereafter falling somewhat.

Air Requirement and Exit Gas Volume—The intake air per ton of material is in the region of 27–55,000 ft³/min for all materials, whereas the exit gas volumes vary more widely, increasing in certain cases to 75,000 ft³/min. It may be noted that high values are associated with porous materials which require a considerable water addition to produce the correct bed texture. It is interesting that these values are of the same order as those found for iron ore sintering, and thus it would seem that the same

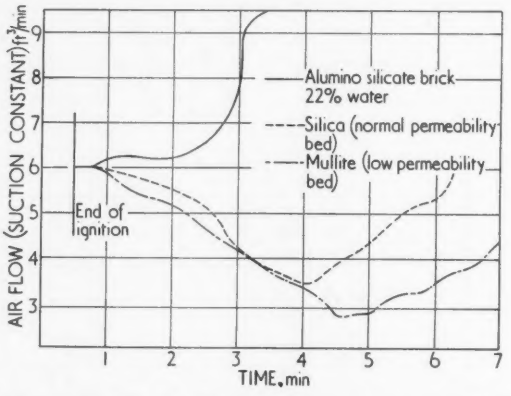

Fig. 9—Variation of air-flow (suction constant during sintering)

Table III
PERMEABILITY OF POROUS ALUMINO-SILICATE BRICK

Water Content, %*	Permeability in B.P.U's			
	Pre-ignition	Post-ignition	Trough	After-sintering
8·7	130–160	95–115	85–105	130–155
22	195–200	120–135	120–135	195–205
32	230–240	140–160	140–150	195–225
40	210	127	125	220–230

* The water content is expressed as a percentage of the total sinter mix, including water.

fundamental principles control the sintering of inert materials and iron ores.

Calcination of Carbonate—When a mixture of marble, coke, and water is sintered it is not possible to obtain the normal temperature distribution down the bed (*see* Fig. 4) since the endothermic carbonate decomposition cannot be completed in advance of the flame front even when 20% of coke is used.

Figure 10 shows the manner in which the temperature varies with time approximately halfway down the bed and near the bottom with varying coke content. It is apparent that whilst the flame front, indicated by the initial rise in temperature to about 800° C, travels down the bed at about the same rate in each case, the time for complete combustion of the coke increases very considerably with increasing coke in the mix.

When marble is mixed with an inert material, it is possible to obtain normal sintering bed temperature distribution, even when two parts of marble are used with one part of inert material (*see* Fig. 4). To do this, excess coke must be avoided since this delays complete combustion and depresses the maximum temperature in the bed.

Thermal Requirements—Using porous alumino-silicate brick as inert material, the water content of the raw mix was varied from 10 to 40% and marble was used up to a maximum of two-thirds of the mix.

Table IV
NET THERMAL REQUIREMENTS OF MIXES

Material	Water, %	Coke Content, parts by weight	Net Thermal Requirement, kcal/g
Alumina	3·1	5	0·32
Mullite	3·1	5	0·32
Silica	3·1	4·5	0·29
Alumino-silicate brick	8·7	5	0·28
	22	about 7·5	about 0·33
	32	9	0·31
	40	about 10·5	about 0·30
Al-Si brick 83% / Marble 17%	19	8·3	0·37
Al-Si brick 67% / Marble 33%	20	about 8·3	about 0·32
Al-Si brick 50% / Marble 50%	16	8·5	0·33
Al-Si brick 33% / Marble 67%	16	about 9·0	about 0·31

This gave rise to a wide variation in the heat requirement for endothermic reactions. For each water and carbonate content, the coke content was varied and a value was found which gave a normal flame front speed and temperature conditions down the bed.

Table IV shows the net thermal requirement (i.e. heat input less heat used for water evaporation and carbonate calcination) per gram of residual solid for each of these mixes and for the normal silica, mullite, and alumina mixes. It can be seen that this figure is reasonably constant at a value of about 0·32 kcal/g.

CONCLUSIONS

Whilst it would be premature to draw detailed conclusions from the initial work described, it is clear that the 3-in. sintering pan is a valuable unit for studying the fundamentals of sintering, and certain broad conclusions may be drawn. The results obtained show that inert materials may be used for studying many of the fundamental phenomena which occur during sintering. Using a wide range of such materials and working with constant initial air flow while maintaining constant suction during

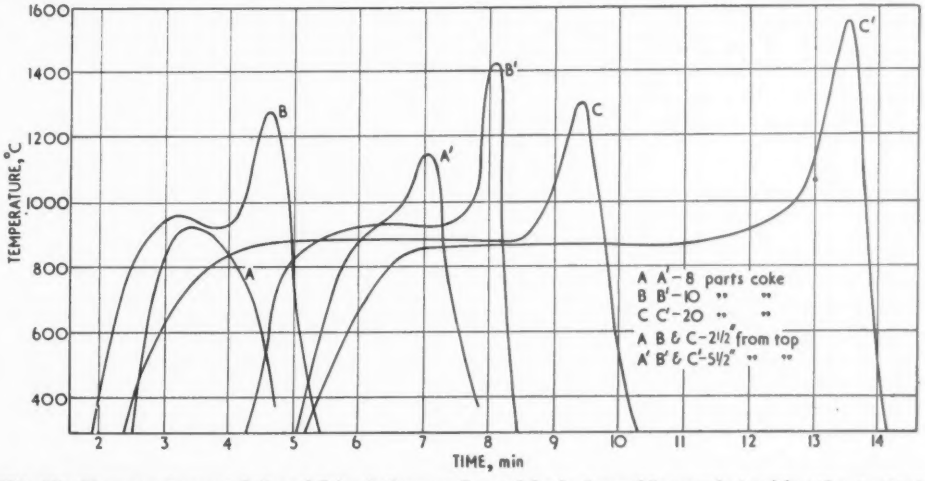

Fig. 10—Temperature at 2·5 and 5 in. below surface of bed of marble varying with coke content

sintering, the flame front travels through the bed at a constant speed which is inversely related to the bulk density of the material. For this reason the quantity of air needed to sinter a unit weight of mix is of the same order for all materials. By the use of inert materials containing widely varying quantities of water or marble, the influence of endothermic chemical reactions has been studied. When the heat required for such reactions is allowed for, the remaining heat, which is that required to raise the temperature of the bed to the necessary level, is the same for a unit weight of any material.

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* These references are included in "Symposium on Sinter," *Iron Steel Inst. Spec. Rep.* No. 53, 1955.

Position Control of Electrical Screwdown Drives

By D. B. Manwaring, B.Sc.(Eng.)

SYNOPSIS

This survey, largely based on the technical press, shows that from 1927 onwards efforts have been made to introduce position control of screwdown. These have been mainly confined to producing three different methods of providing automatic preset screwdown control on structural section mills, sheet mills, and plate mills. It is suggested that because of the inevitable delay in the development of new techniques, maximum economic utilization has not yet been achieved. 1211

SINCE 1927, there has been a recurrent interest in improvements to the existing control of screwdown and at least three different methods of achieving position control* have been evolved.

It has been thought economically worthwhile to install position control of screwdown mainly on wide beam mills, sheet, and plate mills, although there have been isolated examples on other types of mill. Nearly all the development has been on 'preset' automatic screwdown, but maximum utilization of the technique has not nearly been reached.

Following this survey, the possibility of providing position control of screwdown with less initial expense but with adequate standards of reliability and ease of maintenance is being investigated by B.I.S.R.A.

Research is also being carried out on the possibilities of the relatively neglected 'follow-up' type of position control.

This survey was undertaken as a necessary preliminary to the development by B.I.S.R.A. of a position control for a rolling mill screwdown drive; the work done on this forms the subject of later reports. Automatic gauge control, which the title might be considered to include, is specifically excluded from this report.

Many of the installations described which the author was unable to visit have been installed in the United States but the information used from the American technical press was supplemented by letters from the appropriate manufacturing organizations. Several British installations were visited and seen in operation.

THE PRESENT POSITION

Development of position control for rolling mill screwdown has been rather slow throughout the

* A position control in this report is taken to mean an automatic displacement–displacement system. That is to say that when the control handle is moved, the load responds by moving a distance which depends on the amount the control handle moved. If the load responds to a control handle movement by a change in speed whose value depends on the amount the control handle moved, it may be called a displacement–velocity system. Such a system can only produce the effect of a displacement–displacement system by being supervised by a human operator, both at the beginning and at the end of the movement.

Paper PE/N/1/55 of the New Engineering Techniques Committee of the Plant Engineering Division of the British Iron and Steel Research Association, received on 20th August, 1955. The views expressed are the author's, and are not necessarily endorsed by the Committee as a body.

Mr. Manwaring was on the staff of B.I.S.R.A. when this paper was prepared.

world. It has been suggested[14] that the adoption of the technique has been delayed by the cheapness of labour compared to down time, the necessity for operating reliability, the need for simplicity, and the high first costs of installations, especially when older plant has to be modified. As labour costs increase, control equipment grows more reliable, the maintenance man becomes technically more competent, and customer's requirements grow more stringent there will be a stronger case for automatic screwdown control.

In the United Kingdom

Position control is not being neglected in the British steel industry. It is understood to be worked on two 3-high sheet mills, one 2-high sheet mill, and one railway wheel mill. Four other installations are believed to be in the process of development. One is on an armour-plate mill,[30] another is on a slabbing mill, a third is on a merchant mill, and the fourth is understood to be on a structural mill.[31] One of these is being developed in co-operation with the Plant Engineering Division of B.I.S.R.A.

Abroad

As has been indicated, most examples of position control of screwdown are in the U.S.A. It is understood from one manufacturing company that many of the older installations have been removed, but two other companies seem confident that preset automatic control of screwdown is more than holding its own.

In Europe, post-war mill installations[27, 29] have included examples of preset automatic screwdown, while a steel mill in Chile, completed in 1950, is mentioned as having automatic preset screwdown on the breakdown sheet mill. No further details have been noted on this, but the fact that it has been installed so recently implies that the control is considered economically worthwhile for this mill.

TYPES OF MILLS ON WHICH POSITION CONTROL HAS BEEN APPLIED

It has been impossible to derive statistical data either on the methods used for achieving position control or on the types of mill on which it has been employed. It has, however, been possible to obtain some idea of the trends in the installation of position controls.

Structural Section Mills

The earliest reference (in 1927)[6] deals with the position control of screwdown on a wide-flange beam mill. Both the roughing and the intermediate stands were provided with the system. Each stand reduced on three surfaces to produce correct values for flange width, web thickness, and flange thickness, and up to 15 passes were catered for on the roughing stand. It is explained that, as larger beam sections were required, it became progressively more difficult to produce matched speeds and drafts for the extrusion-like process required, until a limit switch form of control was devised. A comment on this, made in 1944,[19] was: " An incidental gain was the saving of an operator in each of the two mill pulpits, but the final justification for the installation of the expensive and complex automatic limit switch control was that it was the only way to definitely ensure the accurate repetitive setting of each of the three sets of rolls for each pass of the schedule and thereby enable properly proportional drafting of the webs and flanges of the beam, with resultant greatly-improved quality and uniformity of products, higher rolling rate, and reduction in scrap loss because of the elimination of long fishtail ends ".

A reference[28] published in 1951 mentions automatic preset screwdown as one standard method of control for this type of mill. At the time of writing (1955) it is understood that a current steelworks expansion scheme in this country envisages the provision of an automatic preset screwdown control on a new structural section mill.[31]

Sheet and Plate Mills

Every manufacturer of an automatic screwdown control has specified his system as suitable for sheet or plate mills. The literature shows that this type of mill has most often had a position control of screwdown fitted. Whilst continuous mills do not use the control, both semi-continuous and reversing mills have done so.

An example of a 4-high reversing plate mill is described[28, 23] which has a 13-pass, two-schedule preset automatic screwdown control governing two 150 h.p. mill-type motors. Synchros are used to drive the error-actuated control system. A Ward-Leonard scheme employing 'shovel' (3-field) generator characteristics is used. The main mill drive consists of two 5000 h.p. d.c. motors giving a roll surface speed range of 400–800 ft/min. The output gauge range rolled is from $\frac{3}{16}$ in. to 15 in. thickness. The first slab was rolled in February 1944.

The application of this control to a reversing universal roughing stand on a 132-in. continuous plate mill is described by Kenyon and Cook.[21] These describe how the Ward-Leonard control of the two 100 h.p. d.c. shunt-wound motors is capable of being preset for 11 passes on a 2-schedule plug board system. A selsyn-driven limit switch with spirally arranged contacts is used. Anticipatory slowing of the motors, forcing of contactors, and slave operation of the manipulators are among the refinements of the system. It is stated elsewhere that one operator alone can control the reversing roughing mill, including approach, main, and delivery tables, screwdown, horizontal and edger roll main drives, edger roll adjustments, and entry and delivery side guards.

The three-high sheet or plate mill has often had an automatic control of screwdown fitted. The example of limit switch control referred to on p. 412 is typical of a case where mechanization of a jobbing mill has allowed it to continue to compete with the modern continuous mill.[18]

Other Types of Mills

Besides structural section, plate, and sheet mills, there have also been examples of position control of screwdown applied to other types of mill. A blooming mill has been provided with a 2-schedule multipass preset automatic screwdown control.[20] Work has also been carried out on position control applied to the screwdown on a railway wheel mill; but no published work on this has come to the notice of the writer.

METHODS OF USING POSITION CONTROL

There is more than one way of operating a position-control system. Furthermore, the method of operating influences the choice of the scheme used for achieving position control. The two main types of operation may be classified as 'follow-up' and 'pre-set'.[8]

The former system visualizes the control as making the controlled unit into an extension of the operator's own limbs. Thus the operator's hand is moved and the controlled unit follows up with a minimum time lag. The preset control conceives the operator as setting up the required position of the controlled unit on his control panel during a slack period in his sequence of operations or even before the commencement of his operating shift, and initiating the motion at the instant required by a simple movement of hand or foot.

Applying these classifications to the control of a rolling mill screwdown, certain general fields of application are apparent. The preset control is to be found where it is desirable to follow a pre-arranged schedule closely without depending on the skill of the operator. Long rolling pass sequences can be handled accurately and quickly by this method. Follow-up control has a different sphere. It is to be looked for where flexibility is the paramount requirement and where rigid schedules have no place.

The two methods are not competitive. Each has its own distinct sphere governed by the type of work upon which the mill is employed.

Advantages[2,3]

Position control of screwdown properly applied, results in two major improvements of performance, viz. increased accuracy and quicker operation. Both these advantages arise because of limitations in the human operator. A machine can be designed to carry out a scheduled quantitative calculation faster and more reliably than a human being. Furthermore, its standard is maintained at the same level throughout the working shift irrespective of the mental condition of its human overseer. This will not be the case with the conventional displacement–velocity control since the operator, here, must keep the load he is controlling under close observation almost all the time. This is an arduous task and must affect the operator's efficiency in time.

A further advantage is that the more exact operation of a position-controlled motor minimizes the amount of inching and overshoot recovery necessary for normal operation. This should result in easier maintenance on both mechanical and electrical equipment.

Those who favour preset position-control of screwdown claim that, in addition to greater output brought about by the advantages of greater speed and accuracy, the product is of higher and more uniform quality. This is because the rolling schedule may be set by a skilled operator who uses the correct drafts for the material. The control ensures that these are maintained in spite of changes of operator or even changes in the same operator.[7, 9, 10, 13, 14 etc.]

The detractors of the preset system emphasize the lack of flexibility for coping with abnormal conditions, such as variations of temperature between ingots. The existence of an overriding manual control would seem to dispose of this objection, however.

The follow-up system does not suffer from this apparent inflexibility since its operation follows the *ad hoc* decisions of the operator.

In either preset or follow-up position control, the task of the operator requires less acquired skill than the usual types of control, so that training periods should be shorter. In some cases, position control may make it possible to employ fewer men and the reduction of the number of operators in the control bridge may lead to a simplified and more efficient arrangement of controls on the bridge as a whole.

However, the economic case for the adoption of position control of screwdown rests not so much on these advantages as on its ability to eliminate any serious time delay during the rolling processes while the screwdown is operating. That this delay can exist is borne out by Grove[5] who says that "out of the total time for rolling an ingot the sum of the periods required for handling by the auxiliary machinery is of the order of 50–60% for blooming and cogging mills and 60–70% in the case of slabbing mills".

There is no information available on the specific delays due to screwdown but the exact locations of delays in the rolling process are being investigated by the Plant Engineering Division of B.I.S.R.A.

Use of Electrical Methods

Existing methods of screwdown control which come under the broad category of position control may be split up into three groups. These will be described in detail later and are:

(i) The limit switch method
(ii) The potential divider method
(iii) The synchro method.

All methods share the requirement for some kind of feedback, i.e. in each case the control may be regarded as a closed loop. The feedback in the first group is discontinuous, whereas in the second and third groups it is continuous. The first group in general suffers from the disadvantage that in the event of overshoot there is no further feedback ensuring reversal and subsequent correct positioning, whereas both the other two groups with their continuous feedback enable the load to be "homed" on to the selected position from either side.

The limit switch method—The pure limit-switch form of position control has been used in a number of installations. A typical example was stated in 1938 to have been incorporated on 16 three-high plate mills.[17, 11, 27] In this system, the limit switch assembly consists of a shaft making one rotation for the whole range of screwdown. On this shaft is mounted one disc for each pass. Each disc may be rotated independently with respect to the shaft by means of a crank, which constitutes the setting up of that pass. Thus the position of a contact on the disc is preset to a desired position relative to the initial angular position of the disc. When the motor is started, the disc assembly is rotated by the preset amount until the contact on the following disc makes with a brush. When this occurs the motor is stopped by the following sequence of events.

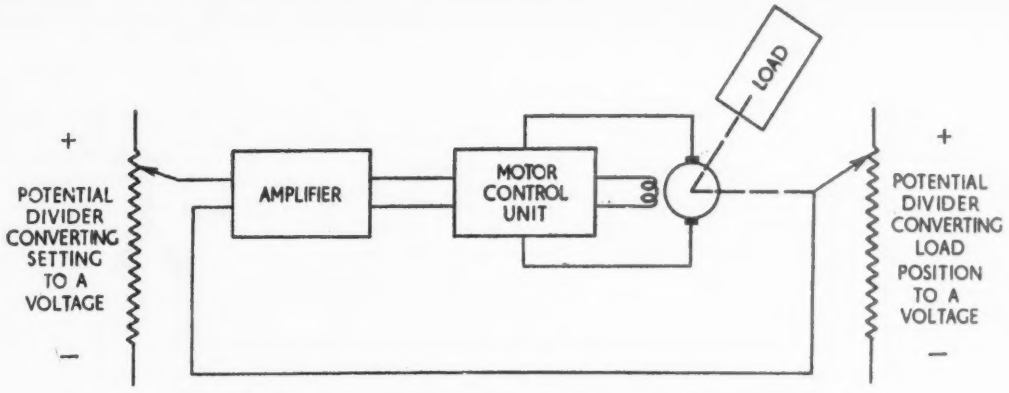

Fig. 1—Basic scheme of position control using potential divider method

A relay is energized by opening a normally closed interlock in series with further contactor coils. This action connects a dynamic braking resistance across the motor armature and isolates one side of the mains, thus combining electrical and mechanical braking to bring the screwdown motor to a standstill.

One of these installations is operating successfully in Britain on a 3-high roughing plate mill. The presence of automatic screwdown control is regarded by one writer as essential to the economical operation of the plant.[18]

The Potential Divider Method (*see* Fig. 1)—Methods of control using continuous feedback have received a great impetus since the 1939–45 war. Two methods of providing this feedback have been used in the control of screwdown. Both compare a voltage or voltages proportional to the position of the object to be controlled, with a selected voltage or voltages. The difference acts as an error signal and this, suitably amplified, is used to move the load until there is no difference between the voltages.

The first approach was to drive a rheostat from the screwdown and compare the voltage developed across this with another voltage selected by pegging in various resistance units. The following method was first described in 1933[9] and has since had improvements in detail which are recorded in a paper published in 1948.[25] A main rheostat is rotated in synchronism with the screwdown motors by means of gears and a selsyn link. The rheostat is divided into steps of resistance each representing perhaps $\frac{1}{2}$ in. of screwdown. The steps are tapped off and connected to a series of parallel conducting bars so that each bar represents a point on the screwdown range. A series of similar bars, equal in number to the number of passes required to be preset, is arranged at right angles to the first set of bars in a parallel plane. The two sets of bars are insulated electrically from each other but wherever they cross they may be joined by the insertion of a plug.

Thus, if each of the upper series of bars represents a pass, then any pass may be connected to any of the rheostat tappings and a finite point on the screwdown range is associated with a selected pass. The arm of the main rheostat which is in step with the screwdown motor is at a unique voltage rigidly associated with the actual screwdown position. Thus an error voltage may be developed between the main rheostat arm and any selected tapping on the main rheostat, and this may be used to drive the screwdown motors to give the roll aperture associated with that main rheostat tapping. Early schemes for this system used d.c. through the rheostat and a polarized contact-making ammeter, but the latest modification described mentions the use of 115 V a.c. across the rheostat and a phase-sensitive balance detector employing thyratons. This, it is stated, is because the earlier method did not lend itself to anticipatory control, i.e. the provision of warning of the approach of the point of zero error.

The above illustrates the general principles but only allows a selection from tappings with comparatively large steps of roll aperture between them. Instead of increasing the number of steps to approach what might easily be impossible requirements, a vernier rheostat system electrically similar to the main rheostat system is provided. This system, powered by its $\frac{1}{4}$ h.p. set-up motor, positions a set of cams which control the movement of the screwdown motor after the final required segment on the main rheostat has been reached. The two systems are inter-connected mechanically by a differential and reduction gear assembly, such that, on pressing the control button for a change of screwdown setting, movement occurs under control of the main rheostat and the preset cams. Once the screwdown motors are positioned, the vernier control starts moving automatically to set the cams ready for the next pass setting. The main rheostat is moved a fraction of an increment at the same time, so that final balance always occurs at the centre of a main rheostat segment.

Anticipatory control is provided by means of an electronic unit and two of the cams on the cam assembly; the stopping sequence provided by these means is two stages of field strengthening controlled electronically and two stages of armature shunt controlled by cams. As the centre of the main rheostat balance segment is approached, the directional contactors are opened and the series brake applied. Should there be any overshoot, the appropriate directional cam initiates a plugging action.

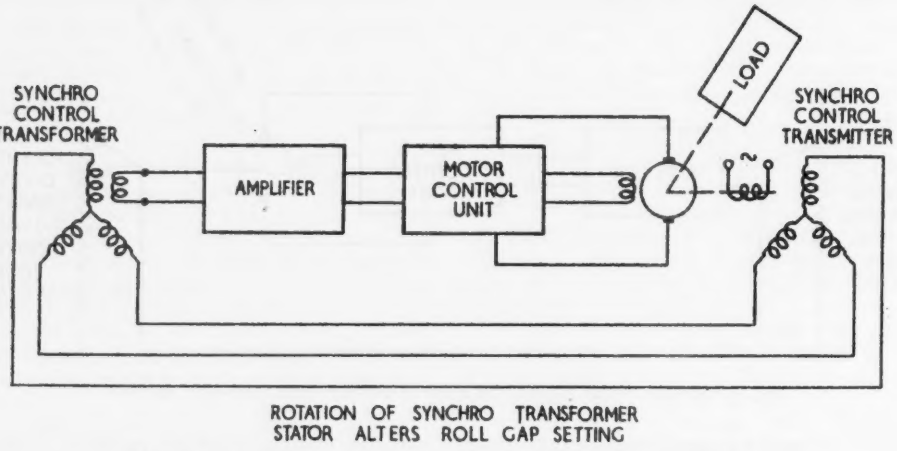

Fig. 2—Basic scheme of position control using synchro method

A typical installation would cover a 16-in. range of screwdown in steps of 0·025 in. but this can be improved upon with little difficulty. Inaccuracies of as low as ± 0·005 in. have been claimed.[16] Most automatic screwdown equipments installed in the U.S.A. have been stated by the representative of a different manufacturer to be similar to the one described above.

Synchro Method (*see* Fig. 2)—The most modern approach to monitored control of screwdown has been to incorporate synchro elements as error-detecting instruments. The BSS term for these units is 'synchro control transmitters'.[4] Each unit consists of a triple winding stator and a single winding rotor. The rotor is energized and free to rotate. The whole arrangement acts as a variable-ratio transformer and is connected to a similar element called a 'synchro control transformer'. This unit has three stator windings which are connected to those of the synchro control transmitter but its rotor is not energized.

When the positions of the two rotors, relative to their stators, are at right angles to each other, there is a position of no energy transfer, but if there is any deviation from this, the rotor of the transformer supplies a voltage which is both a function of the angular deviation and direction-sensitive. Thus it will be seen that these units lend themselves to data transmission and incorporation in feedback loops.

This method has been used, for example, in an installation which called for a multipass preset programme, and accordingly, each preset pass required a synchro control transformer. To achieve the required accuracy, a technique known as 'coarse-fine switching' was employed, each synchro pair being duplicated and the two pairs connected by a gear ratio of 35:1. Then the coarse or slow-moving synchros covered the whole screwdown range without duplication of a working point, but the fine synchro, moving 35 times as fast, repeated their indications of position. The position control worked on the coarse pair until there was no ambiguity possible in the indication given by the fine pair, then the signal given by the fine pair was switched into circuit. This switching operation was automatic and was controlled by selection of a preset point on the curve of error magnitude against displacement. The error from both coarse and fine synchro systems was used to drive a hard valve amplifier, an amplidyne, and finally the screwdown drive.

This example has been applied on a reversing plate mill and a blooming mill.[20] Its technical performance is reported to be good.

Refinements to these Methods

The above three examples of methods of application of position control to screwdown drives have each been developed by a different manufacturing company in the U.S.A. These three, and another U.S. company, have in fact done most of the development of this application. Whilst the approach of each company appears to have remained largely the same, they have improved their products through the years. From the first, certain accessories were regarded as essential to the control system. An overriding manual control has always been stipulated and provided. Some method of allowing for roll diameter variation has always been required. The method adopted varies with the type of control system. When preset programmes have been designed, duplication of the schedule boards has been a standard fitting. Display panels have often been provided as well, to show which stage of the programme has been reached. New refinements have been added with new techniques. Control schemes generally have benefited by the availability of the rotating amplifier which has made possible such advantages as inherent current limit and added speed of response. Power synchro drives have enabled the driven part of the control gear to be mounted away from the mill in a controlled atmosphere. Anticipatory control has been provided in most installations, although it is only required where both speed and accuracy are specified. This has been achieved electronically, mechanically, or by means of tachogenerator feedback, while other techniques such as forcing of contactors, provision of duplicate control buttons to prevent accidental

operation, and the employment of 3-field generators have also been used.

Whilst the above points have been met and covered in industry as a whole, some improvements peculiar to rolling-mill operation have been devised. One system provides final anticipatory control only in the downward direction.[20] Thus, final movement always takes place in one direction and the backlash is taken up. Another refinement is the insertion of a control which allows return to the first pass of a preset programme at any time. The interlocking of the screwdown with the other auxiliaries has also been taken to considerable lengths on some installations. Side guides and edging rolls are controlled in one example by slave limit switches, such that those used on the input are set at slab width and those on the output side at slab width + 4 in., and the whole mill is used on a reversing preset programme.[16] Mechanical feeding equipment is sometimes interlocked so that feed only occurs when the screwdown is set for pass one. Tilting tables for 3-high mills, too, are often automatically controlled to position themselves in accordance with the screwdown programme.

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The Use of Electrical Eddy Currents for the Study of Surface Layers

By A. P. H. Jennings, B.Sc., A.R.C.S.

Introduction

Principle of Measurement

THE USEFULNESS of electrical eddy currents in the study of conducting surfaces lies in the fact that these currents, induced in a conductor by an alternating magnetic field, are confined to the surface layers. The magnitude of these currents and their depth of penetration below the surface depend on the electrical resistivity and magnetic permeability of the conductor, the magnitude and frequency of the applied field, and the disposition of the conductor in the field. In the case of a semi-infinite conducting mass with a plane face, the variation with depth of the amplitude of the eddy currents (and of the magnetic field) from its value W_0 at the surface is given by the expression:[1]

$$W = W_0 \exp\left(-2\pi\sqrt{\frac{\mu f}{\rho}} \cdot x\right)$$

SYNOPSIS

This paper presents the results of an experimental study of the use of electrical eddy currents for examining the surface of conducting material. The work was largely concerned with the study of physical properties and the measurement of coating thickness, particularly that of tin on steel. The distribution of eddy currents in a conductor and their influence on the electrical characteristics of a coil linked with their magnetic field depends on a large number of properties of the material. Great care is required in separating the effects of these properties, and eddy current methods are of greatest use in simple systems where only one of the properties of the material varies.

Eddy currents may also be used for the detection and measurement of mechanical defects such as cracks, and a short description of methods is included. 1252

Paper P/35/55 of the Physics Department of the British Iron and Steel Research Association, received 28th October, 1955.

Mr. Jennings, who was with B.I.S.R.A. when this paper was written, is now with Bailey Meters and Controls Ltd.

where f = frequency of applied field, μ = magnetic permeability (assumed constant), ρ = electrical resistivity, and x = depth below surface.

The quantity $$\frac{1}{2\pi}\sqrt{\frac{\rho}{\mu f}}$$ is generally termed the depth of penetration, δ, and is equal to the depth at which the field intensity has fallen to $^1/_e$ of its value at the surface.

The eddy currents give rise to a magnetic field in opposition to the applied field and they also dissipate power in the conductor in the form of heat. This eddy current heating, which occurs only in the surface layers where the currents flow, is of use when it is desired to give the surface of the conductor a thermal treatment without affecting the bulk of the material, e.g. as in surface-hardening. When it is required to use eddy currents to measure the properties of a surface, the heating effect must be kept small so that changes in these properties are not caused by thermal effects. This means that weak fields must be used.

The eddy currents may be conveniently detected by placing a coil near the surface of the conductor so that the magnetic field of the currents links with the coil and induces in it a voltage which depends on the strength and distribution of the currents. In practice, it is convenient to use the detector coil as the source of applied field by passing an alternating current through it. The electrical characteristics of the coil are then modified by the eddy currents in the conductor. Anything which affects the flow of these eddy currents, e.g. the electrical properties of the metal, the dimensions of the conductor, or the presence of cracks in the path of the currents, may be detected by measuring the modifications in the primary coil.

The apparatus required to make the measurements comprises four units:

(i) A source of alternating current of suitable frequency
(ii) A coil of form suitable for application to the surface to be studied
(iii) A measuring circuit which will respond to changes in the impedance of the coil
(iv) An indicator which presents the results of the measurement in a form that can be interpreted in terms of the variable it is desired to measure.

It should be emphasized that the form of the coil used is of great importance since it will control the amount of electromagnetic coupling between the coil and the conductor. On this depends the way in which changes in the conducting mass are reflected in the coil.

One of the major advantages of the eddy current method is that it is non-destructive, and, in general, can be applied without any special preparation of the test piece.

TYPES OF MEASUREMENT

It has been stated that the impedance of the search coil is influenced by the resistivity and permeability of the conductor, the dimensions of the conductor and its disposition in the field of the coil, and by the presence of mechanical discontinuities, such as cracks, in the path of the eddy currents. In addition, the roughness of the surface will have some effect on the measurements.

Theoretically, any phenomenon which affects the resistivity or permeability of the conductor may be measured. Difficulty of interpretation of the measurements arises from the fact that these properties depend on many variables such as chemical composition, metallurgical structure, thermal treatment, and the presence of mechanical strain. It is therefore only possible to achieve unequivocal detection of the effects of change in one variable when the other variables are constant during the measurement. In practice it is possible to obtain a certain amount of selectivity in the measurement by the use of special electronic circuits having particular characteristics. The interpretation of the measurements under these conditions, however, may require considerable experience in using the apparatus.

Subject to these restrictions, eddy current methods may be used for the following application:

(i) *a.* Study of physical properties of metal
b. Sorting of material according to composition and heat treatment
(ii) Measurement of dimensions such as the thickness of foils or of coatings of one material on another, or the diameter of cylindrical specimens
(iii) Detection and measurement of mechanical defects such as cracks and inclusions.

An experimental investigation of the uses of eddy current methods has been carried out in the Physics Department of B.I.S.R.A. with particular regard to applications (i) and (ii). This paper deals in some detail with these two applications. However, in order to present a fairly complete picture of the range of usefulness of eddy currents, a section on the important field of the detection of defects has been included.

The Study of Physical Properties

If a search coil supplied with alternating current is placed on the surface of a flat conducting sheet (the thickness of which is large compared with the depth of penetration of the eddy currents), then the impedance of the coil will depend on the properties of the conductor but not on its thickness. Thus, for a sheet of any given thickness it is possible to make

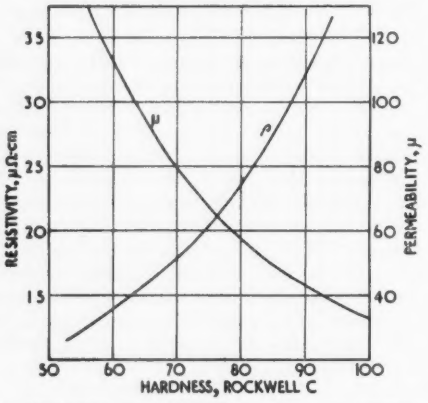

Fig. 1—Variation of resistivity and permeability with hardness, mild steel

the impedance independent of the thickness by using a sufficiently high frequency. The spacing of the coil from the sheet also affects the impedance but the effects of spacing and the effects of the properties of the sheet can be separated by the use of special circuits.

Therefore, unknown metals may be identified by a measurement of their resistivity (or of resistivity in conjunction with permeability in the case of magnetic material) even though the surface of the material may be painted or wrapped in non-conducting material. Conversely, measurements can be made of the thickness of coatings of insulating material on a known metallic base.

The resistivity and permeability of a material depend not only on its composition but on its thermal and mechanical treatment. It is possible to detect differences in composition or thermal and mechanical treatment by the methods described above. One practical application is the examination of cylindrical bar stock for slight changes in composition, the differences from a standard sample being indicated independently of differences in diameter.

The hardening of steel by thermal treatment produces changes in the resistivity and permeability of the general form shown in Fig. 1.[2] It will be noted that the resistivity increases, and the permeability decreases with hardness. It is possible to measure the hardness of uniformly hardened steel by placing a coil around or on the surface of the specimen. Figure 2 shows how the inductance and resistance of a coil wound around a uniformly hardened bar of mild steel varies with the hardness. Both inductance and resistance can be represented by a single graph, since the forms of variation of the two components are very similar. It will be seen that differences in carbon content produce marked effects on the curves particularly at low hardness numbers, so that, in order to measure hardness, a knowledge of the composition is required. Figure 2 also indicates the possibility of measuring the carbon content of plain carbon steels in the annealed state or when the hardness is relatively constant. In the case of steel having a gradient of hardness below the surface, the hardness at the surface may be measured by using a sufficiently high frequency.

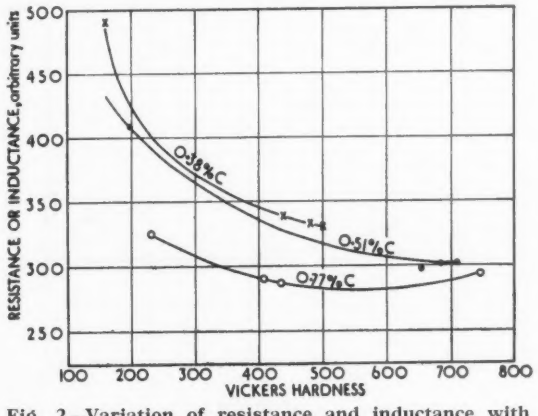

Fig. 2—Variation of resistance and inductance with hardness, mild steel

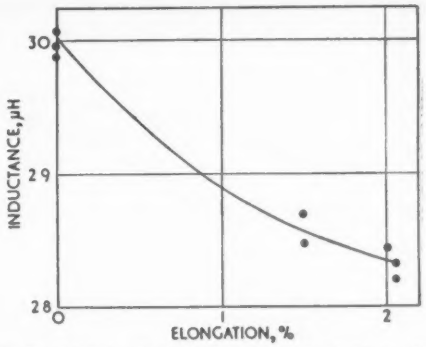

Fig. 3—Variation of inductance with degree of cold work, steel

As an example of the influence of mechanical treatment on the properties of a metal, the graph of Fig. 3 shows how the inductance of a flat coil placed on the surface on a sheet of steel varies with the amount of cold work to which the sheet has been subjected. The sheet concerned has been annealed after rolling, then given a further small amount of reduction by cold rolling. This treatment is designed to improve the behaviour of the sheet when subjected to pressing or deep drawing, and the amount of cold working required is fairly critical. An estimate is made by measuring the percentage elongation produced. The graph shows that the inductance of the coil decreases as the elongation produced is increased. Very few measurements have been made so far and it is likely that the composition of the steel will have considerable influence on the results. However, it is possible that an eddy current measurement may be a better indication of the temper of the sheet than a measurement of elongation.

Measurement of Coating Thickness

In considering the effect, on a coil carrying a.c., of the presence of a specimen consisting of a layer of one material on a base of different material, account must be taken of several contributory factors. When placed on the surface of the specimen, the coil is at a distance from the base that varies with the thickness of the coating. Therefore there will be effects due to:

(i) The fact that this spacing exists
(ii) The properties of the material filling this space.

The coil is also spaced from the surface of the coating by a non-conducting layer consisting of the face of the coil former and any grease or dust on the surface. This will contribute directly to the effect of (i) and will modify the effect of (ii). In addition, the properties of the base material will affect the impedance of the coil.

The first requirement for good sensitivity is that the properties of the coating shall be sufficiently different from those of the base. In the case of non-magnetic materials, this requires a large difference in resistivity, while for magnetic materials the product of resistivity and permeability gives a guide to sensitivity.

Given a sufficient difference between properties,

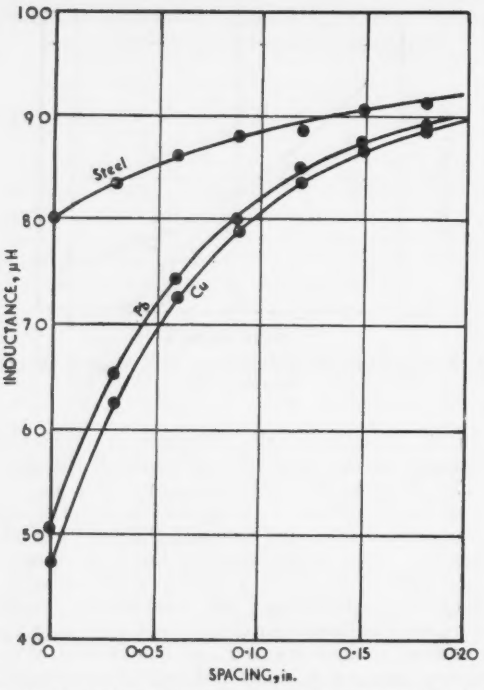

Fig. 4—Variation of inductance with spacing, 320 kc/s

the next requirement is that the eddy currents shall penetrate through the coating and into the base. This is essential in order that the current distribution shall depend on the depth of the interface between coating and base below the upper surface. For conducting coatings, this means that a sufficiently low frequency must be used, since the higher the frequency the less is the depth of penetration. In the case of a highly insulating coating, the attenuation of eddy current intensity is negligible compared with that which occurs in a conductor, and no limit is set to frequency on the grounds of penetration of the coating.

A further requirement is that the eddy currents must not penetrate right through the base (in the case of sheet material or hollow tube), otherwise the current distribution would depend on the thickness of the base and would be affected by the presence of conducting matter below the base. This sets a lower limit to the frequency used. For a given frequency, therefore, there is an upper limit to the coating thickness which can be measured and a lower limit to the thickness of the base which is permissible.

The coil must be wound to suit the form of the specimen. In the case of a flat sheet, a flat coil placed on the surface is used, while for rod or bar of small diameter, a coil fitting closely around the specimen may be used. The aim should be to achieve the maximum coupling between coil and the specimen.

Apart from the general requirements outlined above, the particular conditions that must be satisfied for effective measurements depend on the type and form of specimen to be measured. There are three main categories of specimen to be considered:

(i) Non-conducting coatings on a conducting base. This also covers the case of non-conducting sheets which may be measured if placed on a conducting base
(ii) Conducting coating on a non-conducting base. This group includes metallic foils
(iii) Conducting coatings on a conducting base.

These three groups are dealt with in detail below.

Non-conducting Coatings—The effect of a non-conducting, non-magnetic coating is to act as a spacer between the coil and the conducting base, and the influence on the coil of varying coating thickness is shown in Figs. 4 and 5. It will be seen that the inductance of the coil increases with increasing thickness, and, at the relatively high frequency of 320 kc/s used, the effect of even a magnetic base is to reduce the inductance. The resistance of the coil falls with increasing coating thickness. Thus, while either of the two components of impedance may be used to measure coating thickness, the choice being governed by the nature of the base, a measurement of the magnitude of the total impedance would lack sensitivity because of the opposing changes in the two components. However, by taking account of the phase angle of the impedance it is possible both to measure the coating thickness and to determine the nature of the base, and either of these measurements may be made independently of the other.[3] In this case, therefore, previous knowledge of the base material is not required. The apparatus required, however, is more complex.

Conducting Coatings on a Non-conducting Base—The effects produced by this combination of materials can be considered as being produced entirely by the

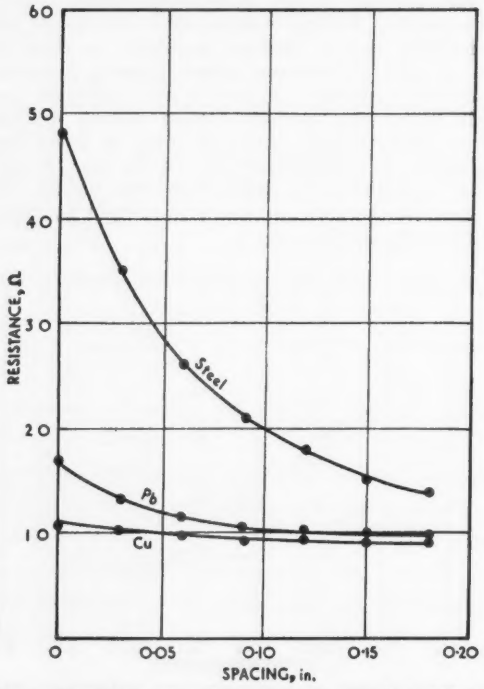

Fig. 5—Variation of resistance with spacing, 320 kc/s

coating, since, because of its very high resistivity, the base will have a negligible influence on the coil. The effects on the inductance and resistance of a search coil placed on the surface of a metallic foil of varying thickness are shown in Figs. 6 and 7. The metal used in this case was aluminium, but the curves are typical of those obtained with any metal. It will be seen that the inductance decreases smoothly with increasing thickness and that the effect of varying the frequency is small. The graphs of resistance/frequency show a peak in the region of 0·001 in. The actual value of thickness at which the peak occurs decreases with increasing frequency, so that the peak can be made to occur at very nearly zero thickness by the use of a sufficiently high frequency. However, as the frequency is increased, the range of measurement is decreased. Generally, therefore, a measurement of inductance is to be preferred.

In addition it has been shown that the measurement of inductance can give a more accurate measure of thickness, and one which is less affected by changes in frequency or in the spacing between the coil and the coated surface.

Consideration of all the above factors clearly indicates that in general the inductance is the component to be chosen for measurement.

Conducting Coatings on a Conducting Base—The general requirements to be satisfied in order to achieve a sensitive measurement have already been described in detail. The main requirement is that the properties of the coating and base shall be sufficiently different.

It would, therefore, be expected that to measure the thickness of a non-magnetic material on a magnetic base should be very easy. The most widely used magnetic material is steel, which is frequently given a coating of another metal either to improve its resistance to corrosion or to give it an attractive surface, or both. Therefore it will be of interest to examine the way in which the presence of a steel base affects the measurements of foil thickness described in the previous section. Figures 8 and 9 show the variation of inductance and resistance of

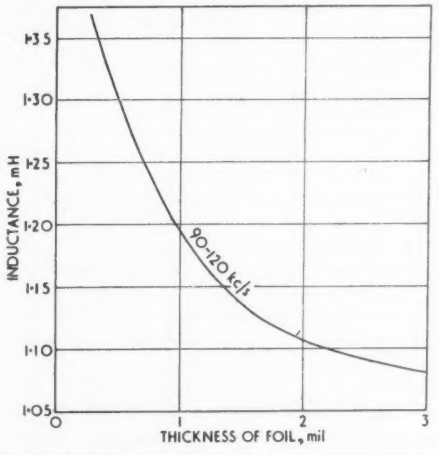

Fig. 6—Variation of inductance with thickness of foil, aluminium

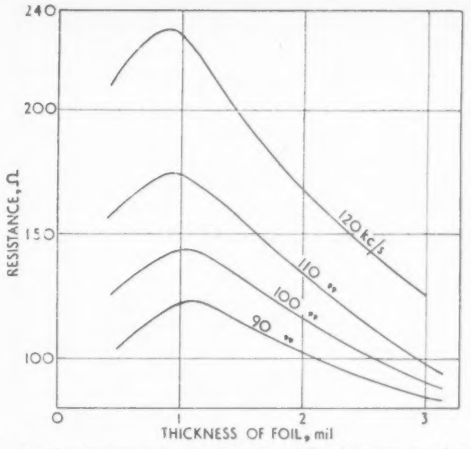

Fig. 7—Variation of resistance with thickness of foil, aluminium

the coil with thickness of aluminium on a steel base, under the same conditions as before.

The inductance varies with coating thickness in the same manner as for unbacked foil, but the slope of the graph is increased for small thicknesses. The inductance is always decreased by the presence of the base at the frequencies used, the curve for unbacked aluminium at 90 kc/s being plotted to allow a direct comparison to be made.

In the case of resistance, the curves again show a peak but it now occurs at about 500 microinches. The resistance is increased by the presence of the steel, and again frequency has a large effect.

Bearing in mind the great similarity between the graphs of Figs. 8 and 9, and those of Figs. 6 and 7, an analysis of the relative merits of measurement of inductance and of resistance in the case of coated steel leads to the same conclusion in favour of inductance. The effect of variation in the properties

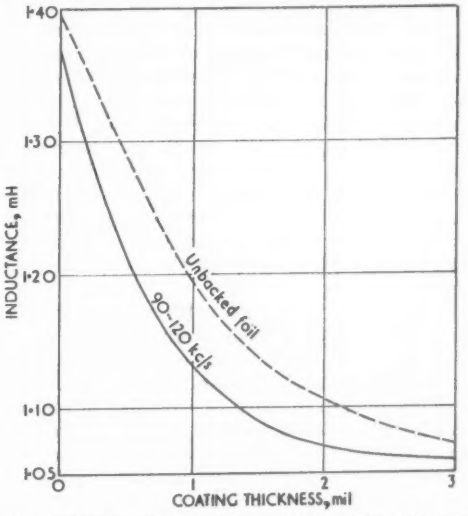

Fig. 8—Variation of inductance with coating thickness, aluminium on steel

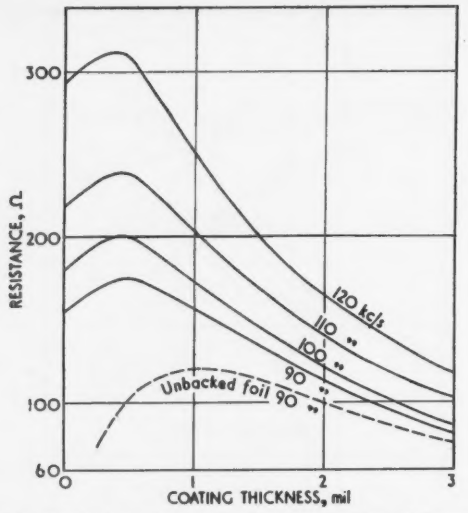

Fig. 9—Variation of resistance with coating thickness, aluminium on steel

of the base is one additional factor to be taken into consideration in the case of a coated base. It has been shown that the inductance is less sensitive than the resistance to changes in the base, using a series of mild steels and a sample of gauge plate as base material. The effect of the base is, of course, greater the thinner the coating, and, particularly where thin coatings are to be measured, calibration for a particular base material would be required.

One of the most important coatings on steel is tin, and an instrument has been developed to measure the thickness of tin coatings.[4] The bulk of the tinplate commercially produced has a coating thickness in the range 15–300 microinches. A fairly high frequency is required for such thin coatings, and the graphs of Figs. 10 and 11 show the variation of inductance and resistance with thickness of tin or steel at a frequency of 1 Mc/s. The main point of interest is that the peak value of resistance now occurs at a coating thickness of 50 microinches. In the actual instrument, an even higher frequency has been used. The resistance peak has thus been shifted so far towards zero thickness that it no longer causes ambiguity in the readings. Because the inductance and resistance both change in the same direction for a given change in coating thickness, it becomes possible to use a measurement of the total impedance of the coil as a measure of thickness, thus considerably simplifying the measuring circuit required.

The presence of the alloy layer between the tin and the steel does not have any appreciable effect on the form of variation of impedance with thickness, except possibly in the case of the thinner coatings, where it has been found that a reading of impedance on a coating that has been deposited electrolytically differs slightly from that obtained on a coating of the same thickness produced by hot-dipping. This difference is sufficient to require a separate calibration of the measuring apparatus for each of the two coatings when the thickness is small.

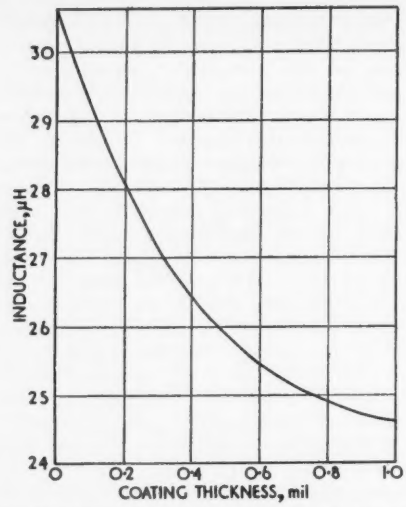

Fig. 10—Variation of inductance with thickness of tin coating, 1 Mc/s

Detection and Measurement of Mechanical Defects

A mechanical defect such as a crack, inclusion, or pipe in a conducting material may be detected by the distortion of the flow of eddy currents in the neighbourhood of the defect, which, in turn, influences the impedance of the coil inducing the currents. To achieve sensitivity, it is essential that the region of distorted current flow is appreciable when compared with the region in which undistorted flow takes place. This requires that the defect shall be near the surface of the sample where the eddy current density is high, and the coil must be placed so that the defect presents the greatest possible obstacle to the currents, i.e. that a large area of the defect is normal to the current flow which would occur in the absence of the defect. The dimensions of the coil must obviously be related to the expected size of the defect.

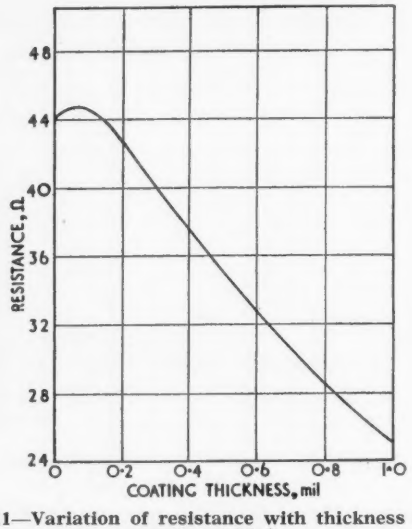

Fig. 11—Variation of resistance with thickness of tin coating, 1 Mc/s

With any practical arrangement of coil and specimen, the direction of flow in the region of high current density is parallel to the surface of the specimen. Therefore, any defect which lies parallel to the surface will offer little obstruction to the current flow, and consequently the detection sensitivity for this type of defect will be low. Thus, eddy currents are of little use in detecting the presence of lamination in sheet material. They are most useful for locating defects which have an appreciable area normal to the surface.

Given the optimum geometrical disposition, detection of the defect is most readily achieved in the cases where the defect presents the greatest possible difference in electrical and magnetic properties from those of the sound material. One of the most common forms of mechanical defect is the crack or non-metallic inclusion which presents a localized region of high resistivity and, usually, unit permeability in the conducting mass. Provided that the defect is at or near the surface, it can be readily detected if surface irregularities are of a low order. As the depth at which the defect occurs increases, the detection sensitivity falls off, not only because of the decay of eddy current intensity with depth, but also as a consequence of the increased relative effect of surface irregularities.

For specimens with large cross-sectional areas, the only practicable form of coil is a flat circular coil placed on the surface of the specimen. With such a system it should be possible to detect cracks immediately below the coil, and, provided that the dimensions of the coil are sufficiently small, to follow the path of individual cracks. For specimens having a smaller cross-sectional area it is possible, as an alternative, to wind a coil around the specimen. With such a coil a more rapid examination of the specimen is possible since the entire surface area is covered during a single traverse of the coil along the specimen. However, the indication obtained at any position gives a measure of the summed effects of all cracks under the coil. If a measurement of the dimensions of individual cracks is required, then the flat surface coil must be used. Cracks which can be detected may be internal defects of a coarse nature or else minute cracks, possibly visible only under magnification, either on the surface or just below it. In ferrous material, a measurement of crack depth may be made in the range of about 0·001–0·025 in.[5]

In the search for defects, what is generally required is an indication of a deviation from a desired specification. A comparison method is commonly used, with two coils connected in a form of bridge circuit, one embracing the sample under examination and the other a standard sample having the desired properties. The bridge is initially balanced using two identical standards, and any subsequent unbalance is due to a deviation in the test specimen. This deviation may be due to the presence of a mechanical defect or it may be due to differences in shape or dimension, or in physical properties. Great care is required in interpreting the measurements. In certain cases, however, where it may be reasonably safe to assume that only one of the many possible sources of deviation is likely to occur, the comparison method allows a very high rate of inspection.

CONCLUSION

Electrical eddy currents can be of great use in the non-destructive study of surface layers of conducting material, by virtue of the fact that their depth of penetration can be altered to suit a particular application by selection of the appropriate frequency of the applied magnetic field. The effects produced by the currents can be conveniently detected by the influence of their magnetic field on the impedance of a search coil placed on the surface of the material. This coil may also be used as the source of applied field by passing an alternating current through it.

The distribution of the eddy currents, and hence their effect on the coil, depends in part on the electrical resistivity and magnetic permeability of the conducting material, and on the geometry of the coil/conductor system. It is possible to measure resistivity and permeability, and certain dimensions of the conductor, by making electrical measurements on the coil. Even in the case of these basic measurements, care is necessary to distinguish between the effects of changes in dimensions and changes in resistivity and permeability. It is also possible to relate the electrical properties of the coil to certain other properties of the conducting material which affect the resistivity and permeability. Among such properties may be cited chemical composition, metallurgical structure, state of heat treatment, mechanical hardness, and degree of cold work. In addition, inhomogeneities such as segregation or mechanical defects may cause local changes in resistivity and permeability. To this list should then be added the dimensional variables, such as the diameter of bars and the thickness of foils or coatings.

In attempting to establish the relationship between any one of these variables and the electrical properties of the coil, difficulty is encountered in separating the effects of the other possible variables, since in all but the simplest practical cases, changes in more than one variable occur. In certain cases it is possible to develop experimentally techniques of measurement which will accentuate the effect of one variable and diminish the effects of others. The interpretation of the measurement under these conditions often depends largely on experience. In view of these difficulties it is essential that any problem of measurement of any variable be considered as a special case.

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Correspondence on the Paper—

The Solubility of Sulphur in Iron and Iron–Manganese Alloys*

By E. T. TURKDOGAN, S. IGNATOWICZ, and J. PEARSON

Mr. **A. J. K. Honeyman** (Steel Company of Wales Ltd.) wrote: The practical considerations discussed in this paper are of considerable importance. The iron-rich part of the iron–sulphur phase diagram as determined by the authors, and the effect of manganese thereon, go a long way towards clarifying the hot-shortness phenomenon in steel. But it must be pointed out that the results can be quantitatively applied only to fully killed steels.

McCance[1] has shown that oxygen considerably reduces the effect of manganese in the Fe–Mn–S system, and it may well have some effect on the solubility of sulphur in the absence of manganese.

Hot-shortness of steel in a continuous strip mill is evidenced by edge cracking and the following table shows the behaviour in this respect of some steels:

	Ingot Iron	Silicon Steel	Rimming Steel	Balanced Steel
C, %	0·03	0·04	0·07	0·20
Si, %	tr.	4·0	tr.	0·05
Mn, %	0·10	0·10	0·30	0·40
S, %	0·025	0·010	0·03	0·05
P, %	0·01	0·020	0·012	0·020
Al, %	nil	0·35	nil	tr.
Occurrence of Edge cracking	Invariable	Occasional	Frequent	Frequen

Edge cracking of ingot iron, is, of course, in practice prevented by holding the steel ahead of the finishing stands to obtain a temperature drop from about 1050° to 870° C.

The formula of Anderson and others quoted by the authors is based on steel killed with aluminium. According to this formula none of the above steels should be hot-short. The steel which is least affected has a low excess of manganese and this is the only fully killed steel shown. This steel is ferritic at all temperatures from the solidus and this may have some bearing on its behaviour.

Edge cracking in rimming and balanced steels can be prevented by increasing the manganese and, in the case of rimming steels, by reducing the state of oxygen (while maintaining a good rimming action) by increasing the aluminium additions to the ladle.

Neither the rimming nor the balanced steels shown on the table would give edge cracking in a conventional plate mill. The speed of rolling and the rate of temperature drop in a strip mill are very rapid, and unless the manganese is high the FeS/MnS reversion may not be completed in time to avoid the formation of liquid FeS during rolling.

It would appear, therefore, that the state of oxidation and the rolling conditions both have a considerable influence on the hot-shortness behaviour of steel. For these reasons, it is necessary to have a much higher manganese content in unkilled steels than that which would be expected from the authors' results.

It would be interesting to have the authors' comments on the degree to which McCance's results link up with or essentially differ from their own.

* *J. Iron Steel Inst.*, 1955, vol. 180, Aug., pp. 349–354.

AUTHORS' REPLY

Dr. **E. T. Turkdogan** (B.I.S.R.A.) wrote: It was unfortunate that no reference was made in the original paper to the work of McCance,[1] who, using the results of Whiteley,[2] indicated that the FeS/MnS ratio in sulphide inclusions in steel, formed by air-cooling unkilled molten metal in a spoon sampler, increased with decreasing Mn content of the steel. This relationship is rather approximate as it is not based on experiments carried out at a constant temperature. An attempt may, however, be made to compare this with the authors' findings. As stated, " Calculations, based on the available thermodynamic data on sulphides and on the assumption that iron–manganese and ferrous-sulphide–manganese-sulphide systems form ideal solutions, indicate that at 1200° C the MnS–FeS solution in equilibrium with 0·37% Mn–Fe alloy should contain about 94% MnS." That is to say, FeS/MnS is 0·064 at 1200° C in the presence of 0·37% Mn in solution as compared with the interpolated value of FeS/MnS = 0·1 at 0·37% and at an unknown temperature from Whiteley's results[2] plotted by McCance.[1]

The authors agree that, to prevent hot-shortness, the Mn/S ratio should be adjusted in accordance with the degree of deoxidation of the steel. In other words, the Mn/S ratio in unkilled steel should be much higher than that in killed steel. Since the solubility of oxygen in γ-iron[3] and most probably in α-iron[4] is very small, the degree of deoxidation should not influence the solubility of sulphur in γ- and α-iron. On the other hand, it should first be borne in mind that in an unkilled steel, containing FeO, an inclusion of low melting point may be formed between FeO and FeS, with a eutectic temperature[5] of 940° C. Secondly, any manganese present in an unkilled steel will react with FeO to form MnO during cooling and the remaining percentage of Mn may not be sufficient to form a MnS-rich MnS–FeS inclusion nor to lower appreciably the solubility of sulphur in iron. To overcome these difficulties it is, therefore, essential to have high (total %Mn)/(total %S) ratio in the steel which is not to be fully deoxidized.

Any calculations based on the authors' results apply to equilibrium conditions; it is, however, impossible to make any accurate corrections for the state of non-equilibrium existing between FeS/MnS inclusions and Fe–Mn–S solid solution during rapid drop in temperature of the metal in a strip mill. Nevertheless, it is expected that the ratio FeS/MnS for a given Mn content in solution in a strip during rolling will be, at any temperature, higher than might be expected from the equilibrium data.

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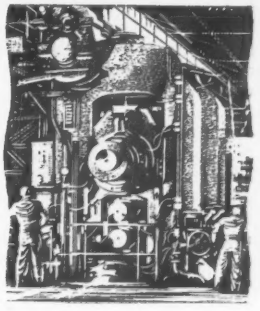
IRON AND STEELWORKS ENGINEERING

The Iron and Steel Engineers Group



Report of the 29th Engineers Group Meeting

The TWENTY-NINTH MEETING OF THE IRON AND STEEL ENGINEERS GROUP of The Iron and Steel Institute was held at 4, Grosvenor Gardens, London, S.W.1, on Wednesday, 14th December, 1955. Mr. A. TAYLOR was in the Chair at the beginning of the Meeting, and his place was later taken by Mr. W. M. LARKE, Chairman of the Group.

At the MORNING SESSION a Paper entitled "The Roller-Straightening of Sections and Rails," by Mr. W. A. J. DINWOODIE (Lamberton and Co., Ltd.), was presented and discussed; a report of the discussion appears below.

The AFTERNOON SESSION was devoted to two papers on "Flying Shears for Bars and Billets," by Mr. R. STEWARTSON and Mr. S. R. PHELPS (Guest Keen and Nettlefolds (South Wales) Ltd.), respectively; the discussion on the papers will be published in a later issue of the *Journal*.

THE ROLLER-STRAIGHTENING OF SECTIONS AND RAILS

This discussion was based on the paper by Mr. W. A. J. Dinwoodie entitled "The Roller-Straightening of Sections and Rails", which appeared in the November, 1955, issue of the *Journal* (vol. 181, pp. 263–272).

Mr. **W. A. J. Dinwoodie** (Lamberton and Co. Ltd.) presented the paper.

Mr. **D. R. Wattleworth** (Workington Iron and Steel Co.): The author has posed the question "How straight is straight?" to which the answer must be "As straight as the customer demands" and that involves consistent straightness.

As with much other industrial equipment, the operator of a roller-straightener has no knowledge of the fundamental basis of its design, and when variations of performance occur he can only apply rule-of-thumb methods for their correction. The only means of immediate correction available to the operator are the vertical and lateral adjustment of the rollers, but these do not always give the desired result. Experience suggests that the profile of the rollers has some bearing on what might be described as the idiosyncrasies of the roller straightener and that the design of a suitable profile and thereafter maintaining it are important factors in achieving satisfactory and consistent results. Roll wear in the rolling mill can result in slight variation in the section, sufficient to produce variations of performance, particularly in what may be called "side sweep", with some roller profiles. No doubt each user has met such difficulties and it may be that a pooling of ideas on roller design would produce something of value.

The development of welded rail track is likely to concentrate attention on the straightness of the ends relative to the rest of the rail, yet this is the very part the roller-straightener cannot influence. The achievement of the required straightness must therefore depend either on the avoidance of bends at this point prior to the roller-straightener, or on their correction by the gag press afterwards. As no ready means of dealing with the problem more automatically can be foreseen, it appears that we cannot yet relegate our gag presses to the scrap heap.

The introduction of the roller-straightener for rails has resulted in increased productivity. Roller-straightened rails per man-hour are some four times what they were when using gag presses. In the United States, however, the gag press has been mechanized and the cost of rail straightening compares favourably with that which would be possible with a roller-straightener. The fact that they have made such a success of the mechanized gag press is likely to delay a change to what has now become standard practice in this country.

Mr Dinwoodie has referred to the shortening of a rail during the roller-straightening process and no doubt there will be some theorizing about this phenomenon. This can be regarded as one of the minor penalties to be paid for the advantages of the process. On his figures, for every thousand rails of the standard length of 60ft put through the machine, some 42ft disappear. As rails are sold by the yard this involves a considerable loss.

Mr. **Dinwoodie:** In dealing with ends of rails or sections, trouble arises because the straightener does not work on the last short length of every bar. It is only when the piece is being bent and is gripped in a triangle of rolls that the straightening effect is obtained. In the

53-in. machine, about 2ft at each end is not bent. If that is distorted when the bar goes to the machine, it will not have been straightened when it leaves.

The length may be reduced by using machines with closer centres, but this results in greatly increased loads. No appreciable reduction of the centres of spindles for heavy sections may be made, because the problem is to get strong enough bearings into the centres required. The present solution, of course, is to avoid the bends in manufacture. Most end-kinks are caused by some accident in handling, or perhaps trouble with the hot saw. If the ends are kept straight, the job of the straightener is made much easier.

The American mechanized gag press is an ingenious machine, but it is slow, and the operator has still to judge his bends. The gag press also delivers a series of local bends to the piece, as revealed by marks where the scale has chipped off. The roller-straightener bends the whole bar; perhaps it is better to have the whole length treated in the same way than to have five or six local points of pressure.

There is no doubt that the roller-straightener will put through a much higher tonnage than the best gag press, and, although the American specification prevents the use of the roller-straightener, there is a lot of interest in roller-straightening. Many American engineers have visited British steelworks and have seen sections and rails being straightened, and the belief is spreading that some alteration should be made to the present restrictive specification on straightening.

Mr. **G. Foster** (Dorman Long (Steel) Ltd.): In roller straightening it is difficult to visualize the forces applied to the piece passing between the rollers. In addition to the bending forces, how is the work done on the steel rail, joist, or angle transferred to that piece through the staightening rollers ? Is it a tension force within the piece pulling it through the straightening machine, or is the piece pushed through by the roller it has just left ? Considering the theory of roller straightening it would be an advantage to know whether the piece within the 5 or 7 rollers is in tension or in compression.

Some years ago my company started to straighten large structural sections in a 53in. centre roller straightening machine. Little was known about the process and the rollers were set in the vertical plane to produce the 'bed pattern' illustrated; straightening in the minor axis was easily achieved. Straightening in the 'deep' or major axis of the joist was initially attempted by setting the rolls offset in plan view which subjected the machine to considerable strains. It was found unnecessary to offset the rollers horizontally, provided that sufficient bending of the piece in the vertical plane was achieved. To take the bend out of the major axis of the biggest joist it is only necessary to stress it beyond the elastic limit of the outer fibres in the minor axis. Do other operators agree with this technique ?

It is easy to understand that if the outer fibres of the flange tips are stressed beyond the elastic limit, the beam will be straightened about its minor axis. However, a heavy beam in this condition has a considerable area of metal at the junction of web and flange which is near the neutral axis and cannot be stressed beyond the elastic limit by pure bending. It seems, therefore, that there is some other force pulling the bend out of the "deep" and it may be a considerable tension force. Does the author's B.I.S.R.A. test include any investigation of the stresses in the steel between the rolls; they could be examined by placing strain-gauges at the neutral axis of the beam being straightened to determine whether there is any longitudinal force acting on it.

Mr. Wattleworth suggests that the shortening of rails during straightening could be a result of densification of the structure, but I would like to add this theory. A rail distorts in cooling because when it leaves the finishing pass, the main body of the metal in the head is at a considerably higher temperature than the flange. When fully cooled the rail finishes with the head the shorter length, the flange is, therefore, in compression and the head in tension, with the head trying to shorten the length of the flange. When the rail is turned up on its base and put through the roller straightening machine the flange is stressed further beyond the elastic limits than the head because it is nearer the outer fibres and the head is considerably stronger. As the head is in tension it pulls the flange which is now beyond the elastic limit and shortens it to coincide with its own length. Our experience has shown that the outlet roller of the large machine is not necessary. What is the experience of other operators ?

In reply to Mr. Dinwoodie's question of whether rails are ever straightened on their sides, Bochumer Verein uses a peculiar process involving two passes with two machines side by side. The first pass is conventional (head up) while the finishing pass is on the side. I believe that at Arbed Belval in Luxemburg, rails are straightened with their webs horizontal.

Mr. **Dinwoodie**: I do not know whether bars are pulled or pushed. A number of driven rollers work on the bar which is probably helped from both ends, but the bending which the bar receives will place most of the layers in severe tension when bent in one way and in compression when bent the opposite way. The metal is heavily worked on and has every chance of releasing any heat stresses and forces locked up inside it.

It would be interesting to hear comments on offsetting the rollers in plan as I think no offset is necessary. If the rolls are properly lined up and the bar is severely bent vertically, it will come out straight in both planes.

About the outlet roller, the bar tends to come downwards from a straightener with adjustable lower rolls and upwards from a straightener with adjustable upper rolls. It all depends where the first carrier roller is situated. If the bar, coming down, will strike the foundations, a roller is necessary to correct this. This roller merely deflects the bar on to the roller table; if that table is brought closer to the machine, no outlet roller is necessary.

Yet some operators cannot do without it. They swear that it contributes materially to the straightening process, and some steelworks would not have a machine without an outlet roller.

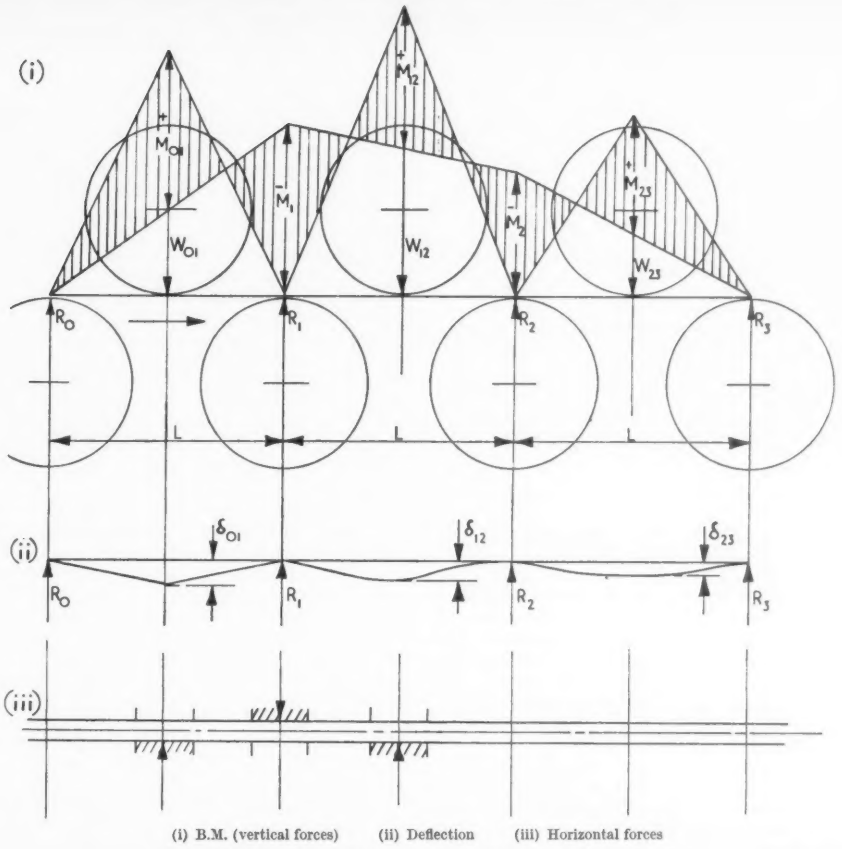
Has Mr. Foster any information on the accuracy of the straightening and the acceptable percentage of rails coming from double machines ?

Mr. **Foster**: I have no concrete information. It is always difficult to get a rail maker to say what percentage he puts back to the gag press !

Mr. **Dinwoodie**: I am sure it is possible to put a strain gauge on the web of a section being straightened, but in fact it has not been done.

Mr. **E. L. Tinley** (Joshua Bigwood and Son Ltd.): The principle of straightening by flexing the material beyond its elastic limit has not changed, but in the past 30 years there have been many improvements in the design and construction of the machines which make use of it. These have come from a better understanding of the plastic behaviour of ductile metals, greater precision in manufacture, the use of modern alloy steels and non-ferrous metals, the incorporation of anti-friction bearings, motorized adjustments, and automatic lubrication.

St. Venant in 1864 supplied the fundamental theory of plastic yielding of beams and since then many others have contributed to the knowledge of the subject. Until quite recently very few engineers were conversant with



(i) B.M. (vertical forces) (ii) Deflection (iii) Horizontal forces

Fig. A—Diagram of forces of 7-roll roller straightener

this work, as the solution of problems of structural and machine design were founded on the 'elastic' theory. Now the subject has become better known and forms the basis of the so-called 'Collapse Method' of constructional steel-work design.

Germany may have been a little ahead of us in building straighteners to deal with the heaviest rails and other sections, but I cannot agree that we ever lagged behind that country in achievement in the field of section straightening (machines were being built in this country for dealing with quite heavy sections, 8in. × 8in. × 1in. angle, and its equivalents 20 years ago). Nor can anything be conceded to the United States with regard to the design of the 'gag press' (horizontal bending and straightening machine.) They may have built bigger machines than we have, but machines with the adjustments referred to on p. 264 were being made here as long ago as 1924.

In the roller-type section straightening machine it is desirable that the greatest forces should be vertically applied. Heavy side pressures may be taken care of by thrust bearings in the roll shaft assemblies, but they give rise to very severe wear on the rolls and represent a greatly increased friction loss. It is fortunate that if a section is yielded by vertical bending moments, very little effort is required to straighten it in the horizontal plane. A possible explanation is that in a straightening machine the material worked upon is subject to rapidly alternating stresses which, for a considerable depth of the section, are in the plastic range. In the Cottrell-Bilby theory of yield, the rupture of the atmosphere of solute atoms which normally locks the lattice dislocations is responsible for plastic flow. As this flow has been initiated by the heavy vertical bending moments, it may be supposed that its direction could be changed by the application of a much smaller force acting simultaneously in, say, a horizontal direction. If this theory is correct it explains why satisfactory results are obtained by straightening rolled steel joists and channels with their Y/Y axes in the horizontal plane.

An examination of the stress distribution in flat bottom rails, straightened with the web vertical or horizontal, will give a clear indication that vertical straightening is the more desirable. In the past, machines have been supplied with rolls for the horizontal straightening of flat bottom rails up to 90lb/yd weight. They are operating in France, Sweden, Turkey, and Bengal, and as far as is known, the results have been satisfactory.

Much experimental work has been carried out to determine the effects of static and dynamic loading in the case of beams deformed beyond the elastic limit and these results generally confirm the current theory of plastic bending. Measurements of the loads involved in roller straightening by large machines acting under production conditions are difficult and expensive to carry out, but when obtained the results are a valuable guide to the solution of design problems.

In calculating straightening loads, it may be helpful to make use of the dimensionless moment/strain curve for the section under consideration. These curves show the relationship between the ratio of the actual bending

moment and the bending moment producing yield stress in the extreme fibres (M/M_y), and the ratio of the strain produced by the bending moment M to that produced by M_y (ϵ/ϵ_y). This scale can be supplemented by a scale showing the depth of plastic yield.

The moment/strain curves flatten out at a limiting value of M/M_y corresponding to full yield of a particular section. These values are approximately as follows:

Section	Limiting Values of M/M_y
Rectangle	1·5
R. S. J. (web horizontal)	1·3
Channel	1·7
Flat bottom rail (web vertical)	1·3
Angle (about V/V axis)	1·3
Hexagon (flats vertical)	1·86

The limiting value of M/M_y for a R.S.J. about the X/X axis is only 1·2, whereas in the case of a hexagon about an axis at right angles to its flat sides, it has a value of 1·86, which indicates clearly that the further away the bulk of the section is from the neutral axis, the less is the value of M/M_y. The bending moment corresponding to full yield is

$$\therefore M = \left(\frac{M}{M_y}\right) M_y \, . = \left(\frac{M}{M_y}\right) \mathrm{Z}\, \sigma_y$$

From the formulæ given by Mr. Dinwoodie for estimating the value of W, it will be seen that there is agreement in the case of rectangles and flat bottom rails, but his value for all other sections would appear to be 1·66.

If we regard the section in the rolls as being a continuous beam over multiple spans with a concentrated load in the middle of each span, the complete bending moment diagram can be drawn. An infinite number of roll settings are, of course, possible but in spite of this the maximum forces which are likely to occur at each roll can readily be determined.

With a 7-roll machine having 3 top rolls and 4 bottom rolls (Fig. A), most work will be done under the first top roll and over the second bottom roll. At these points, under the worst conditions, near-plastic hinges will be developed and bending moments may be taken as those corresponding to full yield. The least work will be done under the last top roll and here the bending moment may be assumed to be not greater than that corresponding to M_y. The moments under the second top roll and third bottom roll may be taken proportionally between M and M_y. This enables the fixing moments to be determined over the intermediate supports and to draw the corresponding diagram. The free moments which are of opposite sign can then be added to the diagram. From this diagram, it will be seen that the bending moment between the first two bottom rolls is, as Mr. Dinwoodie has stated, $WL/6$, from which we obtain the load under the first top roll, but on calculating the reactions on the second and third bottom rolls and the load on the second top roll, we find that these all have values higher than the load on the first top roll, the heaviest load being on the second bottom roll, which may be 25–30% higher than Mr. Dinwoodie's formula would lead us to expect.

Some simple reliable means of determining the depth of plastic yielding is necessary. It has been suggested that the answer may be found by cutting a section which has been through the machine and etching the surface, but I should not think that reliable results could be obtained from this unless the section had first been carefully annealed. What are Mr. Dinwoodie's views on this?

I suggest that the shortening of certain sections, to which Mr. Dinwoodie has referred, is due to lateral plastic flow of the material under the very heavy concentrated loads which occur under the rolls; in the case of rails, the widening of the head and flange which has been observed bears out this view.

Mr. **Dinwoodie:** These are interesting comments on horizontal loads, but surely there is a distinct gain if a plastic effect can be produced by bending about a minor axis to give the yield about the major axis.

The theoretical figure of the amount of plastic yield is a maximum; in practice the figure is probably less. If maximum figures are used for the design of a machine, the operator will have great difficulty in doing any damage.

As the straightener may be used for flow in either direction, all spindles and bearings are made of equal strength. Figures taken from the B.I.S.R.A. test support Mr. Tinley's remarks that the major load generally comes on the first adjustable spindle.

Mr. **E. F. Wooldridge** (United Steel Companies Ltd): These comments relate mainly to the straightening of rails and are largely based on the results of investigation of the stresses and strains imposed on various rail sections during this operation. Since it is virtually impossible to apply strain gauges in the appropriate positions for measuring maximum strain as the rail passes through the straightening machine, the tests were necessarily static but they were designed to simulate actual conditions as far as possible.

The strains induced during straightening have an important influence on the level of the residual stresses resulting from this operation and since as much as half of the bending strain may be permanent, it is clearly desirable to keep this as low as possible. The results of the tests indicate that the maximum strains imposed are well within the flat portion of the stress/strain curve and, therefore, cause no concern from the point of view of strain hardening. Nevertheless, it is desirable that rails should be fed to the straightener for final correction in the straightest possible condition, so that the extent of the deflections imposed by the machine can be kept to a minimum. From observations made at these tests, the extent of the initial side curvature has a particularly important bearing on the roll settings required to produce straight rails, and these in turn influence the magnitude of the loads imposed on the rail during straightening.

Another way of reducing roll loads is to increase the centres of the rollers themselves. The size of the machine must obviously be related to the range of sections to be processed and I disagree with Mr. Dinwoodie that designs should be based on the minimum possible roll centres which will accommodate machine parts of the required size. Although the capital cost of the machine will be minimized in this way it is necessary to have some regard for the effect of short centres on the section being straightened. For a given set of bending conditions the span of the rollers directly influences the intensity of loading which in turn determines the intensity of shear and contact stresses induced in the rail.

Mr. Dinwoodie mentions that the roll loads fall between limits of $\frac{6 \times fy \times z}{l}$ and $\frac{12 \times fy \times z}{l}$ which in the case of a 109 lb/yd flat bottom rail is a wide range (60–120 tons) and has not much significance. In the tests to which I have referred the approximate figures for 75, 98, and 109 lb/yd rails, with the same roller settings in each case, were 70, 90, and 120 tons respectively which suggests that the approximate value is nearer $\frac{12 \times fy \times z}{l}$ than $\frac{8 \times fy \times z}{l}$ as suggested by the author. This indicates that the conditions more nearly represent a beam with constrained rather than free ends, despite the fact that a near-plastic hinge occurs under the rollers, which will tend to mitigate the fixing effect.

It would be unwise to attempt to determine a relationship between vertical load and section modulus from these three sets of results which do not, however, lie in a straight line. Does the straight line relationship which the author mentions relate to conditions in which the same deflections were imposed regardless of variations in the section being straightened ?

Both Mr. Dinwoodie and Mr. Foster referred to the possibility of rails being straightened in a similar manner to sections, i.e. on their sides. Because of the asymmetrical nature of the section, the difference in the restraint exerted by the head and the foot on springing back will tend to cause distortion and it is unlikely that flat bottom rails can be completely straightened in this way. A two-pass system involving one side and one upright pass seems feasible, and has apparently been used, but the advantages of this arrangement are somewhat obscure.

There is a diversity of opinion in regard to the use of deep-flanged top rollers which completely shroud the rail. These are not necessary and, indeed, may be undesirable since rubbing of the rail flange will occur due to the differential speed, resulting in reduced roll life and increased roll turning costs. It does not seem essential for the rollers to be a good fit on the rail since they merely guide the rail in a straight path through the machine without imposing any real horizontal restraint. This contention is supported by the B.I.S.R.A. tests which record the almost complete absence of axial load on the rollers.

Although there may be some advantage in having vertical guide rollers at the ingoing and outgoing sides of the machine for straightening joists and channels, such rollers do not seem to offer any advantages when straightening rails. What are Mr. Dinwoodie's views on this ?

Shortening is probably the result of imposing heavy contact stresses on a section which is simultaneously partially plasticized through bending. This produces compressive stress conditions immediately under the roller in which a certain amount of upsetting takes place and the rail is, of course, only partially restored to its original condition when the load is removed. The shortening effect is a function of the roll load and the degree of shortening is an indication of the intensity of residual stresses induced during the shortening process.

In so far as roller straightening is a more continuous operation than gag straightening and eliminates the human factor, it is a process which might have strong appeal in the U.S.A., and there must be very good reasons why it is not used there. A probable explanation is that the almost complete absence of the flat part of the stress/strain curve (*a–b* in Fig. 5) with high-C rail steels inevitably means that the outer fibres will be strain-hardened before sufficient penetration of plastic strain has been achieved for straightening purposes. This effect is, of course, accentuated by the larger rail sections commonly used in the U.S.A.

Mr. **Dinwoodie:** On the point about the centres, I agree that my paper gives the impression that the smallest centres are chosen; within limits that is the case. The centres determine the size of the machine and to some extent the cost. Mr. Wooldridge has suggested a most useful line of investigation. The rail makers might be able to tabulate straightening results on different sizes of machine and to see whether for successful straightening there is a relationship between section modulus and roll centres.

About the B.I.S.R.A. tests, the figures which I gave for the load on the straightener handling rails was based on a number of rails; but of one size only. That result depends on the accuracy of the reading of that one rail test. The figure for sections, however, is based on a

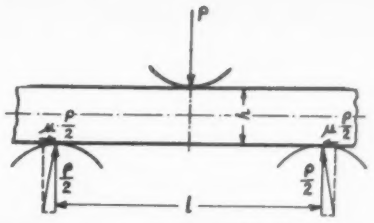


Fig. B—Compression during plastic bending deformation

number of different sections which were tested. The rolls were reset for each section-size, with individual working settings, and the results definitely lie on a straight line in keeping with the section modulus.

Sideways restraint must be applied because a roll or section cannot be left completely free sideways. The original form of straightener, which handled a number of beam sizes, had no sideways constraint and did not function as efficiently as one with rolls fitting the section. In rail straightening, I believe that an improved fit of the rolls on the rails results in better straightening, but apparently that is not Mr. Wooldridge's experience.

With short or difficult pieces, vertical guide rolls help to give a drive to the piece through side-thrust, to help it into the bite of the straightening rolls. However, vertical rolls complicate the mechanism and are not always justified.

Mr. **M. Langen** (Loewy Engineering Co. Ltd.): In dealing with the theory of roller-straightening, Mr. Dinwoodie states that a bending moment should be applied which is about 1½ times bigger than that required to reach the yield point. This is essential since the elongation of the outer layer under the maximum load should be about 3 times as much as the elongation at yield point, so that the material, when springing back to about half of this elongation, still maintains a permanent deformation.

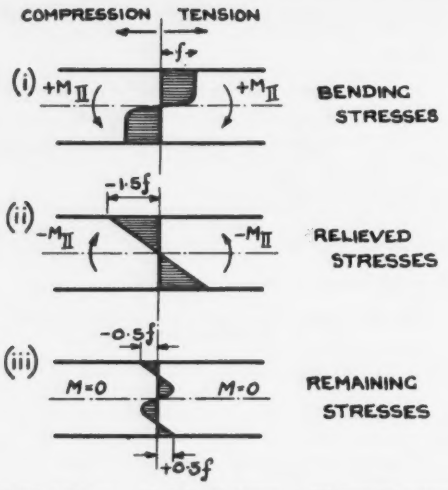
The paper does not mention how the minimum roller pitch should be decided for a given duty and perhaps Mr. Dinwoodie will give details of this. The shearing stress is a very important factor, since if it exceeds a certain amount the material will split at the neutral axis. The deflection in a rectangular section is small if the term $\frac{\text{roller pitch}}{\text{height of material}}$ is small, in which case a big bending load is required. With a bigger bending load, the shearing stress increases and might cause this splitting, especially if the section has a thin web where the stress is much higher then average.

Another factor which must be considered is that with too high a bending load the contact pressure for certain profiles might become too high and mark the material.

It is interesting to see that B.I.S.R.A's investigations confirm that if the material is in a near-plastic condition its resistance to loads working at right-angles is considerably reduced, which explains why it is not difficult to straighten the material in both axes in one pass.

Mr. Dinwoodie mentions that the reason for shortening of rails during the straightening process is not clear, and I offer the following theory.

The length of the bar on the tension side will be increased through the bending, and a corresponding displacement between the surface of the bar and the reaction point takes place. The friction then causes the reaction forces not to run parallel but inclined towards each other,



(i) Bending stresses (ii) Relieved stresses (iii) Remaining stresses

Fig. C—Stresses for rectangular section

so that during the plastic bending deformation a compression appears at the same time (Fig.B).

During the bending process, therefore, the neutral axis will be displaced towards the tension side which causes a shortening of the material during the multiple bending process. This shortening is especially apparent on rounds, but it is also found when straightening sections and rails; in sections to a smaller degree, and in rails to about 0·1% of the length.

Perhaps Mr. Dinwoodie can tell us whether the internal stresses which are created through the straightening process have adverse effects on certain sections. The stresses for a rectangular section are according to Fig. C (i) if the plastic condition is achieved. When the material is released and springs back, these stresses are superimposed by relieved stresses as in Fig. C (ii), which are equal to the internal moment MII. When the material springs back this is a pure elastic deformation and the changes in stress will also be elastic. For this reason the relieved stresses follow a straight line from the neutral axis to the outer layer.

Since the moments in the stress diagram Fig. C (i) and stress diagram Fig. C (ii) have to be equal, the stress on the outer layer is 1½ times the stress in Fig. C (i). Therefore, the outer layer will maintain a stress of −0·5 of the yield stress on the layer which was subject to tension, and of + 0·5 of the yield stress on the layer which was under compression. In addition, internal stresses will remain towards the neutral axis as shown on Fig. C (iii). For channels and beams the remaining stresses in the outer layer are not too high, but rather high remaining stresses in the web cannot be avoided.

A machine with a roller pitch of 53 in. is big enough to handle the largest sections and rails produced at present in this country, but the machine mentioned in the paper should not require a 250-h.p. motor. Assuming that the straightening speed for the heaviest sections is not more than 100 ft/min, a smaller motor should suffice. My company uses for such a machine two motors of 90 h.p. each, which have proved absolutely adequate.

The advantages of a twin drive lie not only in the fact that the second set of rollers can be of a slightly different diameter to that of the first set, hence reducing friction losses, but also in the fact that the moment which has to be transmitted through the gears driving the first two rollers is substantially reduced. This is made possible through the weak characteristics of the motors. The first two driven rollers are more heavily loaded than the rest, but if this overload forces a drop in speed of the first motor, the second motor will automatically get its share, since the two drives are mechanically connected through the material.

Another advantage of this design is that the motors are mounted on the main frame and hence less space is required, which also facilitates the shifting of the machine. Such shifting is a big advantage if two straighteners are employed behind each other. I cannot agree with Mr. Dinwoodie that it is normal to straighten the output of a mill with only one straightening machine. This is true for high output plants with a comparatively narrow programme, but it surely does not apply to a mill which has to be very flexible and cover a wide range of sections. This is more often than not the case in the U.K. and on the Continent where one usually finds that two straighteners are employed to ensure the best possible straightening effect on the various sections.

The design described in the paper has backing rollers for the main shafts. This design was developed in Germany before the war with the main purpose of finding more room for the frame posts between the lower chocks. At that time the frames were mostly made of cast iron, but with fabricated frames and newly developed roller bearings there is now no difficulty in designing a machine for any suitable roller pitch with the main shafts directly supported in roller bearings.

Rolls for rails are very often used as indicated in Fig. 20 of Mr. Dinwoodie's paper, but in view of the disadvantages he mentioned there is another design which uses two side discs and a separate centre disc. Such an arrangement will simplify dressing and substantially increase the life of the rolls. To my knowledge, rails have been straightened in the flat position only when no roller straightener with a sufficiently wide roller pitch was available and in cases when the material was comparatively brittle with a high tensile strength. From my observations, all such rails had to be finish-straightened on a gag press.

The paper mentions that rails are sometimes straightened without difficulty and at other times under the same conditions, a high proportion of rails has to go to

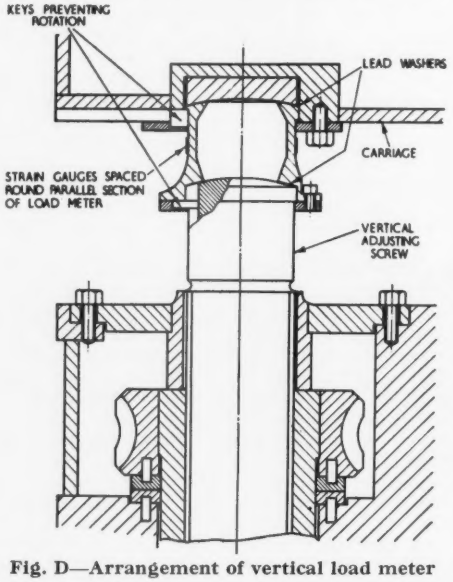


Fig. D—Arrangement of vertical load meter

the gag press. Some if not all of the reasons for such different behaviour are to be found in the purity of the steel, the ingot surface, crystallization and piping, and, above all, in the maintenance of the correct rolling temperature.

The rolls for flats as shown in Fig. 19 can be used only for a limited flat width, otherwise the difference in the peripheral roll speeds will become excessive and cause too much friction. Perhaps a design can be developed to reduce this by having one part of the rolls running idle, the other part being keyed to the shell or spindle. A similar design has proved useful when straightening **Z**-piles. Experiments to find the best possible angle when rolling flats in this manner showed that 23° gives the best results.

With regard to the straightening of broad-flange beams, it is interesting to hear that a roll design might be devised to apply some force direct to the flanges. The biggest difficulty is to cope with variation of the flange width. Perhaps Mr. Dinwoodie will tell us what he has in mind.

He also mentions that roller-straightening will soon start in the U.S.A. Two machines, developed in this country, have been installed by the Bethlehem Steel Co.

Mr. **Dinwoodie:** Internal stresses must always be present. Some layers of the section have not been stretched beyond the elastic point, and they cause the bar to spring back to the straight. The final state of the bar is a compromise and apparently a fairly satisfactory one. It seems impossible to avoid this, except perhaps by stretcher straightening.

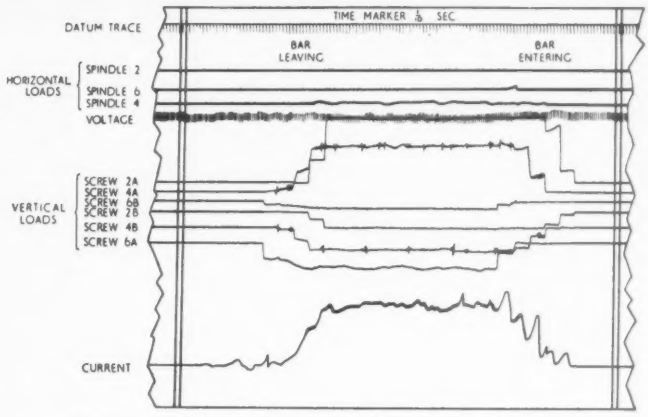
Mr. Langen has said that the two-motor drive allows the first two driven rollers to be of a slightly different diameter from the third and fourth. The difficulty is to ensure that the steelworks arrange their odd rollers in this way. If the rollers on spindles 1 and 2 are of different sizes there is no advantage over a single motor drive.

Logically, each spindle should have a drive of its own. However, the rolls of a straightener are tied together by the piece going through and it seems right that they should all be driven through gearing from one motor drive, then one spindle or pair of spindles cannot work against the others.

The B.I.S.R.A. tests show that the actual power used on one test approached 200 h.p. That seems to leave only a reasonable margin for handling the heavier sections which were not tested. In any case, it is always a good thing to have some spare capacity in a steelworks motor.

I agree with Mr. Langen that roller bearings are excellent for carrying the spindles, and I believe that they are generally used by manufacturers.

Fig. E—Load meters



N.B.—The scale of deflection per unit load differs from trace to trace

Fig. F—Typical trace of 12-channel recorder

The backing roller arrangement has one advantage: there is no difficulty in arranging the axial adjustment of the spindle since it moves across the backing rollers without the need to arrange some sliding sleeve or cartridge, which is necessary with the roller bearing design.

Mr. Langen refers to rolls for rails made in three parts. This has been tried in a British steelworks but not yet with entire success. The idea is, of course, that when the rolls become worn the thickness of the centre piece can be reduced so that the two outer flanges can be brought together to restore the original shape.

In straightening a beam, the forces to bend the flanges must go through the root of the web since the roll bears at this point. The flange has to be bent about its axis of major resistance and for the deeper flanges the applied force must be considerable. Obviously this force tends to shear the flange from the web, and I understand that with some broad flange beams the flange has been torn off.

If some load could be applied directly to the edge of the flange instead of only through the fillet, roller-straightening of these special beams might be made easier. There would be many difficulties with varying flange widths etc., but as the manufacture of broad-flange beams is increasing in this country, it should be examined.

The roller pitch in most machines is generally designed to suit the maximum section in the range to be handled. It is a matter of selecting a pitch which allows the necessary spindles and bearings to be comfortably accommodated. The minimum section is determined by completely different considerations.

To straighten the bar it must be bent sufficiently to stress some layers beyond the yield point, as has been seen. If the roll centres are too wide for a particular section it may be impossible to bend the bar sufficiently. Alternatively, the arc of bend produced in the first triangle will be such that the end of the bar is rejected by the fourth roll.

Cmdr. **J. I. T. Green** (B.I.S.R.A.): Figure D shows one of the vertical load meters in position between the jacking screw and the carriage. The spherical end seatings will be noted. The main concern in calibrating these instruments was to eliminate errors due to the end effects, and to obtain a good repeatable linear relationship between load and strain.

Figure E shows a pair of load meters. The material used was mild steel. Hysteresis effects were considered

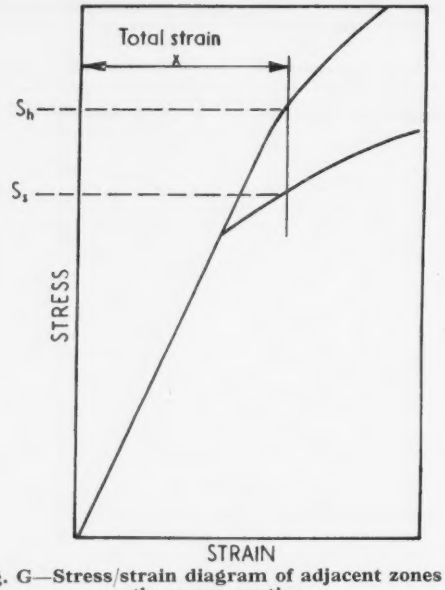


Fig. G—Stress/strain diagram of adjacent zones in the same section

unimportant in measurements of this nature, since the forces were expected to rise steadily to a maximum and stay there while the stock passed between the rollers.

A typical trace from the 12-channel recorder is shown in Fig. F. The absence of any significant measurement of force from the horizontal load meters will be noted. The pairs of vertical screws are identified by the letters *A* and *B*, denoting front and back respectively. Numbers 2, 4, and 6 refer to the bottom rollers in load sequence.

Mr. Dinwoodie has discussed some aspects of the results and we will be very interested to know the outcome of the further experiments to which he refers.

Mr. **D. W. Smith** (Ministry of Supply): Referring to the stress diagram (Fig. 4*b* of his paper) Mr. Dinwoodie states that the higher stressing of the inner layers can be obtained without appreciable increase in stress of the outer layers because the working is carried out on the flat portion of the stress/strain curve. He mentions that the strain can be increased six times without a marked increase in stress.

Presumably this applies to mild steel. Would he say that the same applies in the case of steels of the high tensile structural type which may not show a flat yield ?

Some idea of the forces involved can be gathered by reference to the fully flanged beam where it is said that on many occasions the web has to be separated from the flanges. What changes have taken place locally in the beams that straighten without this separation ? It seems that considerable local work hardening can take place in these zones. Has Mr. Dinwoodie any information on the changes of the mechanical properties near the fillets, particularly changes in the yield/ultimate ratio and in brittle fracture transition temperatures ?

This aspect is of considerable importance in highly stressed structures that may rely on the uniformity of stress/strain characteristics throughout the cross-section for a large part of their safety factor. If there are local variations of considerable magnitude, at strains above the limit of proportionality of the softest zones, a considerable stress differential can develop between the hard and soft zones for equal total strain, the hard zones carrying a much higher stress than the average stress across the section.

Figure G shows the stress/strain relationship of adjacent zones in the same section; if the strain in the section is X, the stress in the hard zone is S_h, and in the soft zone it is S_s.

This effect has been observed in channel sections, and it would be interesting to hear whether Mr. Dinwoodie has any information on the variations in other sections. In such circumstances the safety factor may be less than the designer planned, and he may be unaware of this.

Mr. **H. B. Lloyd** (Workington Iron and Steel Co.): Mr. Dinwoodie has pointed out that whereas with sections satisfactory straightening is possible, the situation with rails is very different. Figures 18 and 20 of his paper show that the support given to sections during straightening is much better than that given to rails, and this may be one of the main factors that cause difficulty in the straightening of rails.

Apart from the longitudinal tensile and compressive forces required to bend the rail around the roller, it seems that there is also a vertical compressive load at the point of support. The stresses arising from this load would be difficult to calculate, but it may be surmised that they are very heavy, and it has been pointed out that there is an overall reduction in the height of the rail as it passes through the straightener. There is a clearance between the sides of the rail head and the roller, and errors of contour of both rail and roller would show that the rail is not straight when it enters the machine. It is exceptional for the line of action of the force between the rail head and the roller to pass through the vertical axis of the rail. Thus, when the rail head is on the roller there is a force tending to tilt the rail over. It seems likely that in the case of rails, this force upsets the process and results in a comparatively large number of rails which are not straight when they leave the machine.

At Workington, a series of tests are being made to reduce the magnitude of local stresses that arise in straightening and to give the section better support during the period when it is being deformed.

Standard bottom rollers have been used, i.e. rollers in which contact occurs over the middle 2¼in. when a 109 lb/yd rail is put through. The top rollers, however, have been deeply recessed and machined to obtain a bearing simultaneously on the crown of the head and on the top surfaces of the toes of the foot. The proportion of the load carried both by the head and the flanges has been varied. Measurements have been made of the deflection of the flanges and of the change in length of the rail. The results averaged from a number of observations are:

Loading conditions	Average flange depression, in.	Increase in rail lengths, in.
All by flanges (head completely clear)	0·064	+0·032
Head clearance 0·015in.	0·0037	—0·046
To template dimensions	0·0047	—0·032
Flange clearance 0·010in.	0·0008	—0·033
All by head (flange completely clear) (Normal straightening)	—0·00375	—0·156

As there is an appreciable reduction of the amount by which the rail shortens, this method apparently reduces local stresses and is a less vicious procedure. On two occasions the operator remarked that the trial results were soft, whereas in fact the trial casts used were in all cases considerably harder than B.S.S.

It is intended to carry out a further trial in which a clearance of 0·020in. will be allowed between rollers and flanges. The best top roller dimensions will then be selected and a test carried out in which the bottom rollers will support the foot over its full width. It seems general practice to support the foot only over the middle 2¼in. and it is not clear to me why this practice is adopted.

There is a difficulty on the method of straightening described. As the rail enters the top roller, contact occurs first on the toes of the foot which momentarily take the full load and they are depressed for the first ½–1in. at the end of the rail. This may be difficult to overcome; various devices such as the use of a short extension piece have been considered, but further investigation will be postponed until the work on straightening technique is completed.

Mr. **A. Taylor** (Cargo Fleet Iron Co., Ltd.): In recent years there has been great concentration on the problem of roller straightening as opposed to gag straightening with consequent improvement in the design of roller straightening machines in order to reduce the cost of production and give a better finished product.

A machine similar to the one discussed in Mr. Dinwoodie's paper is operated by Cargo Fleet and gives good results, but there are certain inherent difficulties in roller straightening as compared with gag straightening, e.g. the difficulty of straightening the end of the rail or section. It may be that shorter centre rolls can be used but there again there is the serious problem of section distortion. This is particularly evident where a wide range of products, such as sections, piling, and rails are required to be straightened by the same machine. This problem must ultimately be solved so that 100% of the bar is straight enough to meet all the inspection requirements.

Closer consideration must be given to the rolling process through the mills from bloom to section so that a high rate of production can be obtained on the straightening machine. In hot sawing, particular care must be taken to avoid any local distortion at the ends of the bars, while in delivery to the cooling bank it must be ensured that minimum distortion of the section occurs during the cooling stage. Thus the bars will be in good condition before the roller straightening operation. Rigid temperature control would also assist this, particularly to reduce variation which occurs in some bars from the same steel cast and is probably caused by finishing at a lower temperature from the finishing pass.

The roller straightener should straighten the bars in the order they are rolled so that during the operation a minimum variation of gauges can occur in successive bars.

Quick changing of the roller straightener should be possible, particularly in a section mill where a large range of shapes are rolled, not always by a large tonnage per roll change, to ensure a high throughput of the machine.

Mr. **Dinwoodie**: Mr. Smith has commented on the figure of six in regard to the stress/strain curve. This would apply to mild steel but certainly not to a number of other steels. Unfortunately I have no record of tests on mechanical qualities made on sections after straightening.

Mr. Lloyd's contribution is extremely interesting in that he seems able to make a rail lengthen or shorten as he chooses. It seems that straightening rolls are not always very exactly finished and there may be considerable variations in diameter in a set.

Manufacturers of straighteners will welcome Mr. Taylor's reminder that the bars should be carefully handled before they come to the straightener.

Machine builders who have heard this discussion will appreciate the comments made by the users, and with further co-operation, improved designs should result.

CORRESPONDENCE

Mr. **J. S. Byam-Grounds** (Joshua Bigwood and Son Ltd.) wrote: Before the war, 7- and 9-roll straighteners with overhung rolls and horizontal as well as vertical adjustment of the straightening rolls were manufactured by Jos. Bigwood designed to straighten beams up to 18 in. × 6 in., 8 in. × 8 in. × 1 in. angles, and 90 and 100 lb rails. Overhung rolls have been used for many years.

In *British Engineering*, May, 1947, Mr. Tinley described the design of a heavy 7-roll straightener for 24 in. × 7½ in. joists, or 130 lb sorbitized rails. Roll centres of 53 in. with a driving motor of 250 h.p. were proposed at that time, which may be compared with the figures arrived at by Mr. Dinwoodie, though Mr. Tinley's design was based on rolls mounted between housings and a power retracted outer housing.

Axial roll adjustment was introduced in about 1924, in addition to the conventional vertical adjustment and the advantages of pinch rolls, usually on the outgoing side, were utilized in 1930. The value of vertical pinch rolls at the entry side of the machine is questionable, but on many sections, especially channels, axial adjustment of the rolls to counteract side sweep can cause damage to the flanges. From my experience, it is better to counteract side sweep by pressure from driven vertical rolls, cross adjusted at the outgoing side. As Mr. Dinwoodie points out, operators' techniques vary and different views are held on the advantages of the different forms of adjustable horse rolls, found mostly at the outgoing end of heavy machines. There is considerable argument on whether rails should be straightened vertically or on their sides. Improved straightening is obtained by working the bar in its normal vertical position, but the writer has seen for himself the difficulties of feeding these rails into the machine when they arrive very badly curved from the cooling bed. It is suggested that this could be overcome by some form of mechanical feeding device, but owing to the varying curvatures, some loss in time in entering each bar would be incurred and in this case it would have been virtually impossible. Consequently straightening on the side was adopted, though it was agreed that vertical straightening would have been infinitely preferable. It would seem here that means of counteracting the curvature during cooling, which are now employed, and greater control at the mill should always permit straightening in the vertical plane.

In the machine described by Mr. Dinwoodie, it is noted that the lower rolls are adjustable with some advantage in the elimination of "lost movement." Does not this, however, make it essential for the entry and exit tables to be adjustable for height for different sections? A case which tends to support this view that axial adjustment applied to side-straighten heavy, wide beams or channels is not particularly effective, may be of interest.

Some years ago we designed and built a machine, not for straightening but for cambering deck beams. This machine was provided with fairly complex powered adjusting means, both in the vertical direction for the top rolls, and axial adjustment on all top and bottom rolls. It had a pair of driven vertical pinch rolls on the outgoing side intended to be used only as retracting rolls, while the camber or side sweep was to be applied by axially adjusting the rolls progressively through the machine. In practice it was almost impossible on the short centres to obtain effective curvature of the bar by this means without damaging the section, and after considerable trial the solution which gave, and continues to give, an effective result was to apply the curvature by cross-adjusting the vertical pinch rolls on the outgoing side, employing the horizontally disposed rolls for pre-straightening and positively feeding the bar through the machine.

A number of questions, the answers to which would be of considerable interest, arise from Mr. Dinwoodie's paper. Firstly, could he supply some data on the rolling friction due to the differential speed of the contact surfaces of the rolls, and relative figures of the power absorbed in this way compared with the actual work done in deforming

the section? From this arises the question of the rise in roll temperature due to friction, the heat from which is sometimes transmitted to the front bearings of the roll shafts with serious results.

With regard to operating speeds, these generally fall between 100 and 400 ft/min, the latter being on the high side, but research into the effect of speed on effective straightening would be of interest and also any observations available as to whether the power absorbed is directly related to the speed once a state of plastic flow is introduced in the work piece.

Several continental manufacturers dispose their first two straightening rolls as a pair of horizontal shaft pinch rolls, the object being to assist the drive through the machine of the more badly bent pieces. In an 8-roll machine, for example, this reduces the number of effective passes, but it would be interesting to have users' opinions on the advantages of this arrangement, which is also applied to some heavy continental plate levellers.

Another serious problem is the roller straightening of flat bars, to which reference is made by Mr. Dinwoodie in Fig. 19. This is a conventional method of straightening flats in their smaller sizes but is not, in my view, appropriate for heavier sections, from considerations both of the difficulty of mechanically feeding the flats into the machine at an angle, and complicating the straightening adjustments necessary in that horizontal or axial adjustment must be made to every vertical pressure adjustment required. The aspect ratio of flats capable of being roller straightened without imparting a twist to the bar is generally regarded as being of the order of 6 or 8:1. Where possible it is usually more convenient to straighten the bars in the vertical plane or in a two-way straightener with two groups of rolls on horizontal and vertical shafts.

A further comment on which some difference of opinion might be expressed is that in the roll set-ups for beams and channels. As they are shown in Mr. Dinwoodie's diagrams, a joggling effect can be set up on the web, especially in the case of channels if unsupported along the middle portion. Roll pressure must be applied as far as possible at the fillet, and this can be assisted by relieving slightly the face of the lower rolls below the web of the section, as shown in the diagram.

With regard to roll materials, the self-lubricating value of chilled iron rolls, which reduce pick-up and improve surface finish of the product, must be considered, although at times their use may not be economically possible.

One of the main problems of roller straightening is the inability of this method to straighten right up to the end of the section. One reason for the American preference for gagging sections, especially in the heavier sizes, would be the necessity of wide centres in the roller straightener which prevent effective straightening to the end of the bar, whereas this can be done on a gag press.

Gag presses with mechanical rotating and feeding devices are extremely quick, and, if skilfully operated, they produce very straight bars. In normal work, localized stresses at the straightening points in gagging eventually tend to reassert themselves, whereas roller straightening does provide a continuous application of stress along the full length of the bar.

In the heavy machine described by Mr. Dinwoodie, the overhung rolls are relatively short and their deflection would not be detrimental in the straightening of rails, but it would be interesting to know whether there are any means provided in his machine for tilting the roll shafts to counteract for deflection when straightening wide beams or broad-flanged beams, and for this type of work there is surely some definite virtue in a machine with the rolls disposed between housings.

Roller straighteners are not designed for rectifying bad rolling, and extreme variations in tolerance between bars in any one batch can completely invalidate the use of a roller straightener for this specific purpose. Similar types of machines with opposed pairs of rolls exist for this purpose.

One of the greatest difficulties facing manufacturers of roller straighteners at the present time is the need to straighten alloy steel bars in high tensile ranges but of relatively small sizes. These must be treated on extremely short centres, but impose loads on roll shafts which cannot be related to the small centres required due to the intrinsic design of the machine. It may be important to investigate means of backing up the roll shaft bearings as described in Mr. Dinwoodie's machine or of reverting to the earlier forms of construction in which the roll shafts were supported in the housing on both sides. The latter system does not, however, fully answer the problem and some means of supporting the work rolls themselves may require investigation.

Mr. **P. Morris** (British Iron and Steel Federation): wrote: Some more information about the arrangements for feeding and guiding sections into the straightening rolls with particular reference to the safe operation of the machine would be appreciated.

(1) Would the author say if mechanical feeding of sections from the straightening machine completely eliminates manual handling?

(2) Are the side guards and rollers which guide the sections into the machine adequate to steady the sections or rails and check any undue movement at the free end?

(3) During straightening, is there any likelihood of pieces of rail flying should a rail break in the straightening process, and is it desirable and practicable to provide guards against this contingency?

(4) In the paper, Fig. 14 shows an open fence with operators standing inside the fencing; Fig. 15 shows an unfenced machine, while in Fig. 16 the machine is fenced for its whole length with a raised portion of the guard opposite the rollers. Is it necessary for machine operators to be in such close proximity to moving parts of the machine as shown in these photographs, as if this is so, there would appear to be a field for investigation to limit manual handling of rails and sections.

AUTHOR'S WRITTEN REPLY

Mr. **Dinwoodie** wrote: In reply to Mr. Byam-Grounds, it would not be easy to measure how much of the motor power is used in overcoming roll friction, and I have no experience of the heat generated causing trouble with the spindle bearings.

With a straightener having overhung rolls, there will obviously be a deflection of the spindle when it comes under load. If the spindle is of adequate size and properly supported, the deflection will be small and not objectionable. It is possible, by adjusting the vertical screws relative to one another, to set the spindle at a slight angle to the horizontal to counteract any possible deflection.

The straightener with rolls between housings is less liable to deflect but is at a disadvantage for roll-changing and for roll-setting since the rolls are not easily accessible.

On the points made by Mr. Morris, practice in handling varies between steelworks and with the size of machine. Generally on the heavier machines, bars are entered successfully from roller tables with entry guides, using perhaps a lifting roller, and without manual handling.

The ends of bars do not whip about to any extent and I imagine that the accident record is good. The users should be consulted for this information.

N E W S

Announcements and News of Science and Industry

IRON AND STEEL INSTITUTE

Special Meeting in France

Awards and Distinctions

The following awards and elections were announced at the Opening Session of the Special Meeting in France at the Sorbonne on the afternoon of Tuesday, 5th June, 1956, by Dr. H. H. Burton, C.B.E., and Baron Walckenaer, Presidents respectively of the Institute and of the Société Française de Métallurgie.

Elected to Honorary Membership of the Institute

Monsieur Jean Raty, Président de la Chambre Syndicale de la Sidérurgie Française and Chairman of the Reception Committee for the Meeting in France.

Monsieur Henri Malcor, Président de l'Institut de Recherches de la Sidérurgie and Président de la Compagnie des Ateliers et Forges de la Loire.

Elected to be Honorary Vice-Presidents of the Institute

Baron Walckenaer, Président de la Société Française de Métallurgie and Président de la Société Métallurgique de Normandie.

Dr. Eugène L. Dupuy, Honorary General Secretary and a Past-President of the Société Française de Métallurgie.

Elected to Honorary Membership of the Société Française de Métallurgie

Dr. H. H. Burton, C.B.E., President, and Mr. K. Headlam-Morley, Secretary. Silver Medals of the Society were also presented to them by Baron Walckenaer.

Messages of Greeting

The following messages of greeting were read by Dr. Howard Biers, Honorary Member.

From Dr. Ernest O. Kirkendall, Secretary of the American Institute of Mining, Metallurgical and Petroleum Engineers:

Recalling especially the delightful days so many of our members spent with you almost exactly one year ago, the President and Board of the American Institute of Mining, Metallurgical, and Petroleum Engineers, on behalf of all its members wish you a very happy and successful meeting in France. Please also extend this greeting to all our French friends.

From Mr. W. H. Eisenman, Secretary of the American Society for Metals:

Dear Doctor Burton:

It is with the greatest pleasure that I send greetings to you and to the members of The Iron and Steel Institute on behalf of the American Society for Metals as you are convened in Paris.

We wish you to know how much we appreciate the very cordial and sincere reception you gave our members during the European meeting of the metallurgical societies last Spring. We most sincerely hope that as many of you as possible plan to give us an opportunity to return your many courtesies by coming to the Second World Metallurgical Congress which will be held under the auspices of the society in the City of Chicago, November 2 through 8, 1957. With kindest personal regards and best wishes.

NEWS OF MEMBERS

Dr. **M. D. Ashton** has left the Physics Department of the British Iron and Steel Research Association to join the Atomic Energy Commission of the Government of Israel.

Mr. **J. A. Evans** has become a Licentiate member of the Institution of Metallurgists. He has also left the Hoffmann Manufacturing Co., Ltd., Chelmsford, and has taken up an appointment as Assistant Manager of the Alnico Plant, Murex Ltd., Rainham.

Mr. **S. R. Howes** has been appointed a Director of The United Steel Companies Ltd. He has also agreed to serve for a further three years as consultant for work study and operational research.

Mr. **C. Lang** has left the Ironmaking Division of the British Iron and Steel Research Association at Normanby to take up an appointment with the Atomic Energy Authority.

Mr. **G. F. Lilly** has left Canada to take up a position in the Applied Research Laboratories of the United States Steel Corporation, Monroeville, Pennsylvania.

Mr. **W. H. Lowther** has become a Licentiate member of the Institution of Metallurgists and has gained the Technological Certificate of the City and Guilds of London Institute.

Mr. **A. Tomlinson** has transferred from Associate to Fellow of the Institution of Metallurgists and has also been appointed Supervisor of Laboratory at the Engineering Research Section of the Ford Motor Co., Ltd., Birmingham.

Obituary

Mr. **James Dale** (*elected* 1930), of Larkhall, Lanarkshire, on 31st January, 1956.

CONTRIBUTORS TO THE JOURNAL

A. G. Haynes, B.Sc.—Research Metallurgist with The Mond Nickel Co., Ltd.

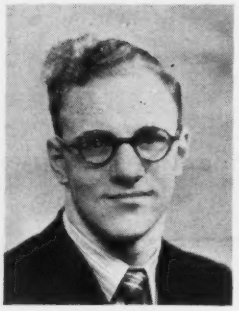
Mr. Haynes was born in 1927 and was educated at Handsworth Grammar School, Birmingham. He attended the Birmingham College of Technology and in 1949 was awarded an Engineering (Metallurgy) Degree at London University. In 1950 he gained the Diploma of Postgraduate Studies in Metallurgy from Birmingham University.

Mr. Haynes joined The Mond Nickel Co., Ltd., in 1944 and has been concerned with various researches in the ferrous metallurgical field.

R. Haynes, B.Met., Ph.D., A.I.M.—Technical Officer, Research Department, Imperial Chemical Industries Ltd., Metals Division.

Dr. Haynes was educated at Belle Vue Grammar School for Boys, Bradford, and at Sheffield University, where he was awarded the degree of B. Met. with first-class honours in non-ferrous metallurgy, the Mappin and Nesthill Medals, and the degree of Ph.D.

A. G. Haynes



R. Haynes

From 1951 to 1954 he was assistant lecturer in metallurgy in the University of Leeds and, since 1954, has been a Technical Officer in the titanium group of the Research Department of Imperial Chemical Industries Ltd., Metals Division, Birmingham.

A. P. H. Jennings, B.Sc., A.R.C.S.—Senior Physicist with the Development Department of Bailey Meters and Controls Ltd.

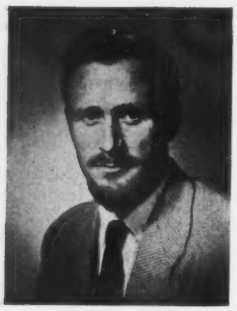
Mr. Jennings graduated in 1944 from Imperial College with B.Sc. and A.R.C.S. in Physics. On leaving college he served in the R.N.V.R. (Special Branch) with duties in the field of Communications. In January, 1947, he joined the Instrument Section of the Physics Department of B.I.S.R.A. as a Scientific Officer, later becoming a Senior Scientific Officer. During this time his work was largely concerned with electromagnetism and non-destructive testing. Mr. Jennings took up his present appointment in January, 1956.

T. H. Lonsdale—on the staff of the Rocket Division of the De Havilland Engine Co., Ltd.

Mr. Lonsdale obtained a commission in the Mercantile Marine in 1945 and subsequently transferred to the Communications Branch of the Foreign Office. He later studied Geology and Mathematics at the University of London and joined the Physics Department of B.I.S.R.A. in 1953. He took up his present appointment in 1955.

D. B. Manwaring, B.Sc.(Eng.)—on the staff of the Ministry of Supply Fighting Vehicles Research and Design Establishment.

Mr. Manwaring was born in September, 1925, and was educated at Paston Grammar School, North Walsham, Norfolk, and at Leeds University. He served in the Royal Navy from 1943 to 1947 and attended University from 1947 to 1950, graduating with first class honours in Electrical Engineering. He was with the Metropolitan-Vickers Electrical Co., Ltd., from 1950 to 1953 as apprentice and Junior Engineer, and then with B.I.S.R.A. until March, 1956.



A. P. H. Jennings

J. R. Pattison

D. T. Steer

D. T. Steer, B.Sc.—Technical Assistant in the Operational Research Department of the Steel Company of Wales Ltd.

Mr. Steer was born in 1926 and educated at Neath Grammar School. He graduated from University College, Swansea, in Mathematics and Physics and has served with the Welsh Guards in Germany and Palestine. He joined the Steel Company of Wales Ltd. in July, 1951.

D. F. Nettell, B.Sc.(Eng.), A.M.I.Mech.E., A.M.I.E.E.—Senior Engineer of the Automation Section, Research Division, Powers-Samas Accounting Machines Ltd.

Mr. Nettell was born in March, 1920, and was educated at Wrekin College and University College, Swansea. He served an apprenticeship to the Electrical Engineer, Great Western Railway (Swansea Docks), and was on duty with the Royal Engineers from 1939 to 1946, mainly in the Middle East. After the war Mr. Nettell joined the Mechanical and Electrical Engineers Department of the Southern Region of British Railways, leaving in 1952 to join B.I.S.R.A. He has been with his present organization since December, 1955.

J. R. Pattison, B.Sc., D.I.C., Ph.D., A.Inst.P.—on the staff of the Physics Department of the British Iron and Steel Research Association.

Dr. Pattison graduated as B.Sc.(Hons.) in Physics and Mathematics from London University and joined the Research Department of A. C. Cossor Ltd. to carry out work on radio valve design. After leaving to join the Metal Box Co., Ltd., as a Physicist, he obtained the B.Sc.(Hons.) degree of London University in Special Mathematics by evening study and subsequently returned to the University to carry out research for a higher degree. In 1951 he was awarded the Diploma of the Imperial College of Science and Technology for research carried out in the Royal College of Science and in 1952 obtained the degree of Ph.D. for work in the field of internal friction in magnetic materials. He took up his present post in 1952, and is now engaged on research into the thermal properties of materials, heat transfer problems, and pyrometry.

IRON AND STEEL ENGINEERS GROUP

By invitation of the Steel Company of Wales Ltd. a meeting of the Iron and Steel Engineers Group will be held in South Wales on Thursday and Friday, 4th and 5th October, 1956.

The Meeting will be devoted to presentation of papers on the "*Engineering Aspects of a Modern Basic Bessemer Plant*," by Dr. C. Herman of Demag AG, and "*The Planned Change-over of a High Lift Slabbing Mill to a Universal Mill*," by Mr. C. E. H. Morris and Mr. R. N. Dale of the Steel Company of Wales Ltd.

The Meeting will include visits to the Margam and Abbey Works of the Steel Company of Wales Ltd.

A notice about the Meeting is being sent out to all members shortly.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

Open Days—Sheffield Laboratories

The British Iron and Steel Research Association will hold two Open Days at the Sheffield Laboratories on

Thursday and Friday, 6th and 7th September, 1956, for representatives of member firms.

The Open Days will provide the opportunity for demonstrating the progress which has been made by the Divisions housed at Sheffield—Mechanical Working, Steelmaking, and Metallurgy (General) — since the premises were opened in November, 1953, by H.R.H. The Duke of Edinburgh, K.G.

The Mechanical Working Division, for example, will be mounting a series of displays relating to wire-drawing (including high-pressure lubrication), work on forging problems, developments in hot and cold rolling, and studies of sheet metal working characteristics. The Steelmaking Division will show various aspects of research into electric-arc furnace operation and economics, advances in ingot feeder-head design, and progress in the immersion-casting technique for steel strip. Open-hearth furnace instrumentation will be demonstrated by displays including the B.I.S.R.A. scale model O.H. furnace, equipped with a calorimeter hearth and apparatus necessary for the study of flame characteristics and convective heat transfer. The Division's Process Chemistry Section will display the vertical high-temperature globar furnace used in the investigation of sulphur pick-up by melting steel from the impingement of oil droplets.

Metallurgy (General) displays relating to electrical sheet steel research will include work on the effect of impurities on the magnetic properties of silicon-iron, and studies of strain-ageing in α-iron. Exhibits will also be on show illustrating investigations into grain-boundary properties and their relation to internal friction, and studies of static hysteresis curves for soft ferromagnetic material. An extensive display of advanced methods of analysis will also be mounted, including microchemical, absorptiometric, spectrographic, and vacuum fusion methods.

The many static displays will be reinforced by a series of working demonstrations—notably of such developments as the continuous casting of steel, and the use of automatic gauge control on the 14-in. experimental rolling mill.

While the main emphasis will understandably be concentrated on the work of the Mechanical Working, Steelmaking, and Metallurgy Divisions, those other sections of B.I.S.R.A. located in London, Swansea, and Normanby will also be represented by minor displays. The various services developed by the Association over recent years will also be illustrated, and the associated research organizations housed at the Sheffield premises—the Cutlery Research Council, the File Research Council, and the Coil Spring Federation Research Organization—will also be represented.

The laboratories will be open from 10 A.M. to 5 P.M. and luncheon and afternoon tea will be provided for visitors. Invitation cards and further details will be issued in the near future.

Conference on Heat-treatment Practice

The conference, organized by B.I.S.R.A. and held at Ashorne Hill near Leamington Spa on 5th and 6th June, was attended by about 180 members representing steelmakers and steel users. Mr. W. C. Heselwood of the United Steel Companies Ltd. was chairman and Mr. H. Allsop of Brown Bayley Steels Ltd. vice-chairman. There were three sessions: (*a*) distortion and cracking problems, (*b*) heating for forging and treatment, and (*c*) transformations.

Mr. F. D. Waterfall, of Imperial Chemical Industries Ltd., and Mr. P. E. Clary, of the Ford Motor Company Ltd., presented papers at the first session. Mr. Waterfall dealt with various factors influencing cracking and distortion such as volume changes (due to temperature changes and transformations), uneven cross-section, presence of a case or decarburization, and grain size. He gave illustrations of these and considered briefly methods of minimizing distortions which may occur. The importance of the correct application of martempering, for it to be successful, was referred to. Mr. Clary discussed the particular problems of the motor manufacturer. He advocated the use of presses during quenching to prevent distortion, rather than its subsequent correction, for example by cold straightening which had attendant hazards. He was in favour of a British Standard hardenability specification as in his experience steels from different sources, although conforming to the same present British Standard, could vary in their response to heat-treatment. It was extremely important to keep the distortion of gears to a minimum, and the advantages of gas carburizing were described in this connection.

Mr. O. Hirston and Dr. F. W. Jones, both of Brown-Firth Research Laboratories, and Mr. J. E. Russell of English Steel Corporation Ltd., presented papers at the second session. Mr. Hirston considered the principles of equipment to ensure good heat flow in furnace charges. He dealt with the subject in three parts: (*a*) the liberation of heat from a flame and the way in which it is transferred to a furnace charge, (*b*) the relative importance of radiation from solids, natural and forced convection, and (*c*) the consideration of a number of basic furnace designs. Dr. Jones gave examples of the application of heat-flow calculations to the different stages of the heat-treatment cycle of large ingots and forgings. These dealt with the avoidance of too rapid heating or cooling which would result in clinking of the forging or the presence of high residual stresses; soaking times for forging, hardening, or tempering; time for the completion of transformation during the annealing treatment. Mr. Russell discussed the advantages and dangers of rapid heating for forging. He described the B.I.S.R.A. experiments on rapid heating of small ingots and billets, and referred to works' experience. His talk included heating by induction and electric-resistance.

Mr. H. Allsop, of Brown Bayley Steels Ltd., and Dr. W. Steven, of the Mond Nickel Company Ltd., presented papers at the third session. After describing the construction of isothermal diagrams, Mr. Allsop proceeded with their application to the final heat-treatment of finished parts and the interstage heat treatments involved in the processing of wrought alloy steel and discussed the limitations of their direct applicability. Dr. Steven commented on the relative advantages of the various methods of presenting continuous-cooling diagrams and gave an assessment of the information provided by these. He considered the various methods of forecasting from such diagrams the behaviour of steel continuously cooled from the austenitizing temperature.

There was lively discussion at each of the sessions and it was generally felt that the conference had been very successful.

AFFILIATED LOCAL SOCIETIES

Ebbw Vale Metallurgical Society

The following Officers and Committee have been elected for the session 1956–57:

President	W. H. R. Bird, M.A., B.SC.
Vice-President ..	J. T. Mills
Hon. Joint Secretaries	F. W. Lewis, W. B. Williams, L.I.M., and W. E. Williams
Hon. Treasurer ..	T. Jones, A.C.I.S.

Committee

J. J. Beese	W. D. Jenkins, B.SC.
L. Bull, B.SC.	A. Meo
W. J. Davies	D. L. Mills
P. Edwards, A.I.I.A.	H. F. Padbury, A.I.M.
A. W. Ellis, A.M.I.E.E.	R. C. Powell, B.SC.
I. Giddings	F. E. Probyn
W. Goatman	J. F. Smith
I. Harries	J. B. Thickins, B.SC.

Leeds Metallurgical Society

The following Officers and Committee have been elected for the session 1956–57:

President	A. Lenton
First Vice-President	P. A. Green
Secretary	Dr. P. Feltham
Treasurer	A. Lenton

Committee: Dr. W. R. Berry, W. L. Bolton, K. Hill, N. S. Martin, F. K. Neath, L. H. Wadsworth, Dr. N. J. Petch (*ex officio*), with the addition of the following Past Presidents: C. Breckon, C. Burrell, and H. Ward.

EDUCATION

Developments at Leeds University

The Council of Leeds University have approved a reorganization of the Department of Coal Gas and Fuel Industries with Metallurgy and Chemical Engineering. Under this reorganization the present department will be replaced by a school to be called the Houldsworth School of Applied Science. It will be constituted of three departments: the Department of Gas Engineering and General Fuel Science with Ceramics, directed by the Livesey Professor, Professor A. L. Roberts; the Department of Chemical Engineering, directed by the Brotherton Professor (to be appointed); and the Department of Metallurgy, directed by the Reader in Metallurgy, Dr. N. J. Petch.

The work of the three departments will be co-ordinated by a special committee.

University of Nottingham

W. Canning and Co., Ltd., of Birmingham, have established a research scholarship of the value of £600 p.a. to be held in the Department of Metallurgy in the University of Nottingham. The scholarship will be awarded for research in the field of metal finishing.

The Electro-Chemical Engineering Co., Ltd., of Woking, Surrey, have agreed to give £300 a year for three years to the Department of Metallurgy towards the cost of a scholarship for research in metal finishing.

NEWS OF SCIENCE AND INDUSTRY

National Industrial Safety Conference, 1956

Over 600 delegates, including visitors from overseas, attended the National Industrial Safety Conference at Scarborough from 11th to 13th May, 1956. The Conference, which was organized by the Royal Society for the Prevention of Accidents, was opened by the Rt. Hon. Iain Macleod, M.P., Minister of Labour and National Service, and the Presidential Address was delivered by Sir Howard Roberts, C.B.E., D.L., J.P. The President presented the Sir George Earle Trophy for industrial accident prevention to Sir George Barnett, H.M. Chief Inspector of Factories, who accepted it on behalf of his staff. Amid applause, Sir George handed the Trophy to the most junior qualified Inspector present, Mr. J. Pyburn. Several papers on industrial safety were presented at the Conference and these, together with the discussion, will be published later.

Compendium on Insulation Materials

Newalls Insulation Co., Ltd., of Washington, County Durham, have recently issued a compendium on insulating materials effective against heat, cold, and sound. This contains full technical data on the range of products manufactured by this firm and is extensively illustrated, including many photographs in colour. It is divided for easy reference into sections on heat insulation, insulating bricks, 'Paxmarine' combined heat and sound insulation, sprayed 'Limpet' asbestos, noise reduction and acoustic treatment, and cold insulation.

Tinplate Production at Velindre

Production of tinplate on a small scale began at the Velindre works of the Steel Company of Wales Ltd. in July. The target for late 1958 is 9½ million boxes a year and developments at Velindre will form a major part of plans to expand the Company's output.

Exchange of Visits with Soviet Steelmakers

A further exchange of visits between British and Soviet steelmakers has been agreed. A Soviet steel delegation is expected to visit the U.K. in the autumn and at the invitation of the Ministry of Ferrous Metallurgy of the U.S.S.R. a British delegation, led by Dr. T. P. Colclough, C.B.E., Technical Adviser to the British Iron and Steel Federation, left for Moscow in June. Other members were: K. C. Barraclough (Thomas Firth and John Brown Ltd.), Dr. C. Booth (Steetley Magnesite Company), W. O. Campbell Adamson (Richard Thomas and Baldwins Ltd.), T. Dennison (B.I.S.F.), F. Kennedy (Dorman Long (Steel) Ltd.), J. A. Kilby (Colvilles Group), A. H. Meadley (Stewarts and Lloyds Ltd.), R. Sewell (United Steel Companies Ltd.), E. Voice (B.I.S.R.A.), and R. Wilcock (Samuel Fox and Co., Ltd.). Among the plants to be visited were the Magnitogorsk Metallurgical Combine and the Novo Tagilsk Metallurgical Works, two of the largest integrated plants in the Soviet Union, the Chelyabinsk Metallurgical Combine, producing special steels, the Chelyabinsk Tube Works, a refractory plant at Nizhni Tagil, and the Ural Research Institute of Ferrous Metals at Sverdlovsk.

Co-ordination of Advice to Ironfounding Industry

An exchange of views has recently taken place between the British Cast Iron Research Association and the National Industrial Fuel Efficiency Service to ensure that proper co-ordination exists in the technical advice both organizations offer to the ironfounding industry. It has been agreed that the two bodies can co-operate to the advantage of the industry.

The Research Association is the body to which the ironfounding industry looks for research, development, and advice over the whole range of its processes. The N.I.F.E.S. is concerned with fuel problems only. It is not engaged in research, but is concerned to improve the fuel practice of all sections of British industry.

Through its liaison services, the B.C.I.R.A. has been successfully advising ironfounders on specific problems which are encountered in their own works. The field work on fuel that the Research Association undertakes is mainly confined to melting and heat-treatment processes and is necessarily, therefore, smaller than that carried out by N.I.F.E.S., who have an engineering staff organized on an area basis from offices in 15 cities in the U.K. The B.C.I.R.A. will therefore recommend ironfounders who are concerned about the use of fuel for space-heating or steam-raising to consult N.I.F.E.S., who will in turn refer to the Research Association any problems that fall outside its experience.

Mechanical Engineering Open Days

The Mechanical Engineering Laboratory, East Kilbride, Glasgow, is to hold its first Open Days on 20th and 21st September, 1956. Applications for invitations, stating which day is preferred, should be sent to the Director.

New Pontypridd Laboratories

The 150th anniversary of the founding of Brown, Lenox and Co., Ltd., was coupled with the opening of new laboratories at the Newbridge Works, Pontypridd, Glamorgan, on 12th June, 1956.

Rolling-Mill Conference—Leoben

The Fachausschuss für Walzwerks- und Maschinenwesen of the Verein Eisenhütte Österreich is organizing an International Rolling-mill Conference at the Montanistische Hochschule, Leoben, Austria, for 20th to 22nd September, 1956.

Meeting on Automation—Brussels

The Association Belge pour favoriser l'Étude des Verres et des Composés Siliceux is arranging for the end of October, 1956, an international meeting on "*Control, Regulation, and Automation in the Fire Industries*," i.e. glass, ceramic, glaze, cement, power plants, and the iron and steel industries.

Fuel Efficiency Refresher Course

The National Industrial Fuel Efficiency Service will hold their third annual refresher course in Oxford for works and plant engineers from 24th to 28th September, 1956. Full particulars may be obtained from the Area Engineer, N.I.F.E.S., Ailsa House, 181 Kings Road, Reading.

DECHEMA Annual Report

The 1955 Annual Report of DECHEMA, the Deutsche Gesellschaft für Chemisches Apparatewesen, has been received and contains detailed information on publications, research work, and meetings. Further copies of this German-language work are available without cost from DECHEMA, 16 Frankfurt am Main, W.7 Postfach, Germany.

Italian Metallurgical Convention—Rome

The National Convention of the Associazione Italiana di Metallurgia will take place in Rome from 7th to 10th October, 1956. This will mark the tenth anniversary of the Association.

Work of Industrial Research Associations

A booklet recently published by the Department of Scientific and Industrial Research, "*Combining for Research*," sets out the history and present-day work of Industrial Research Associations. There are now more than 40 Associations sponsored by D.S.I.R., which have a combined annual income of about £5 million.

Ore-handling Plant for N.S.W. Steelworks

The Fraser and Chalmers Engineering Works of the General Electric Co., Ltd., through its Australian associate, British General Electric Co. (Pty.) Ltd., is to construct an ore-handling and preparation plant for the Australian Iron and Steel Co., Ltd. The plant, which is to be installed at Port Kembla Steelworks, New South Wales, will handle iron ore, ranging from 4 in. cube to dust, at the rate of 800 tons/h. Sinter-conveying equipment is also included.

New Cold Rolling Mill

Steel, Peech and Tozer, of Rotherham, are spending £180,000 on a new cold rolling mill and associated annealing equipment, which will enable output of narrow steel strip for the strapping, tube, and bicycle industries to be increased by about 50%.

Plant for New Indian Steelworks

Davy and United Engineering Co., Ltd., of Sheffield, are to build rolling mill and railway wheel, tyre, and axle plant worth about £7 million for the new integrated iron and steelworks which the Government of India is to establish at Durgapur in West Bengal.

Changes of Name and Address

The American Institute of Mining and Metallurgical Engineers has been renamed the American Institute of Mining, Metallurgical, and Petroleum Engineers Inc., although there is no change of address from 29 West 39th Street, New York 18, N.Y., U.S.A.

The offices of the American Iron and Steel Institute are now at 150 East 42nd Street, New York 17, New York, U.S.A. (telephone OXford 7-5900).

Following the closing of the divisional offices of Hilger and Watts Ltd., all matters affecting sales, service, administration, and accounts should be addressed to 98 St. Pancras Way, Camden Road, London, N.W.1 (telephone GULliver 5636; telegrams Sphericity, London, Telex).

Safety Products Ltd. have removed to Holmethorpe Avenue, Redhill, Surrey (telephone Redhill 4304/5).

The telephone number of the Research Laboratories of the General Electric Co., Ltd., Wembley, has been changed to ARNold 1262.

Industrial Publications Received

Booklet on the diamond tool industry in 1955—Industrial Diamond Information Bureau.

Illustrated leaflet on reinforced grinding wheel—Norton Grinding Wheel Co., Ltd.

Technical brochure on 'SMZ' alloy as a ladle addition to cast iron—British Electro Metallurgical Company.

Illustrated leaflet on 'Celfor' shallow hardening steel—Sanderson Brothers and Newbould Ltd.

Leaflet on phosphate coating process for ferrous metals—Jenolite Ltd.

Illustrated brochures on stainless-steel tubes and fittings; booklet showing range of products; table of steels used for 'Metior' stainless-steel tubes—Talbot Stead Tube Co., Ltd.

Technical leaflet on the 'W–D Gasmaco' Oil Gasification Plant—Woodall-Duckham Construction Co., Ltd.

Illustrated brochure on 'Atomat' nucleonic thickness gauges—Baldwin Instrument Co., Ltd.

Illustrated brochure on the 'Metalectric' direct-arc melting furnaces—The Incandescent Heat Co., Ltd.

Export list of mining and metallurgical equipment—Centrozap, Stalinogród.

DIARY

16th–21st Aug.—Institute of Physics (Non-destructive Testing Group)—Symposium on X-ray Microscopy and Microradiography — Cavendish Laboratory, Cambridge.

24th Aug.–7th Sept.—Canadian National Exhibition—Toronto.

29th Aug.–5th Sept.—British Association for the Advancement of Science—Annual Meeting, Sheffield.

ABSTRACTS OF CURRENT LITERATURE AND BOOK NOTICES

Iron and Steel Manufacture and Related Subjects

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ORES—MINING AND TREATMENT

Open-Pit Taconite Mining at Mesabi, United States. J. Grindrod. (*Min. J.*, 1955, **245**, Sept. 2, 258–260).

Iron Ore Carriers for Britain. Sir Charles Goodeve and J. S. Terrington. (*Shipping World*, 1955, Oct. 19, 371–377, Reprint). A study is made of the optimum sizes and design features of ships for the carriage of iron ore to Great Britain. Home and overseas ports concerned in the British ore trade fall into 3 classes: shallow, medium, and deep ports capable of taking ships up to 8000, 14,000, and 20,000 tons respectively. Opportunities exist for economic operation if ships are built in classes to correspond to the maximum possible size in each class. Deepening of any port should be done so as to bring it into the next higher class.—B. G. B.

Underground Transport of Mechanically Loaded Ore. T. Karlen. (*Jernkontorets Ann.*, 1955, **139**, (9), 763–802). [In Swedish]. The author discusses the relative advantages of rail-mounted ore wagons, mobile shuttle cars and scrapers, and conveyor belts. Design, method of operation, and characteristics are described, together with possible load capacities per man-shift or machine-shift.—G. G. K.

Treatment of Low-grade Taconite Iron Ores. (*Iron Coal Trades Rev.*, 1955, **171**, Dec. 16, 1477–1478). Brief details are given of the plant installed at Silver Bay, Minnesota, for the treatment of low-grade taconite ores from the Merabi Range. Pelletising and sintering of the green pellets are described.—G. F.

New Directions in the Planning of Sinter Plants. A. B. Patkovskiĭ. (*Stal'*, 1955, (3), 208–215). [In Russian]. A three-fold increase in sintering capacity in the U.S.S.R. is anticipated in the next few years, and this article reviews some new developments in sinter-plant design and operation. The characteristics of foreign sinter plants are briefly considered and a typical U.S.S.R. design is illustrated. The need for research on sintering problems is stressed.—S. K.

Improving the Quality of Kamȳsh-Burunsk Sinter. G. P. Ostrovskiĭ. (*Stal'*, 1955, (2), 114–118). [In Russian]. An account is given of the beneficiation of two ores from the Kerch peninsula, one friable, the other dense, and the sintering of the concentrates. Special attention is given to measures by which sinter quality has been improved. The special features of the sintering process are: the moisture-content of the concentrate often exceeds 23%; the heat-content of return fines is used to dry and preheat the mix; solid fuel is used for ignition; the sinter is cooled with sea-water. Planned improvements in practice relating to sinter are briefly outlined.—S. K.

Agglomerating Fine-Sized Ores with Low-Temperature Coke. C. E. Lesher. (*Min. Eng.*, 1955, **7**, Oct., 944–948). A description is given of the "Orcarb" process, in which fine concentrates of calcined particles of taconite, hematite or magnetite are coated with 10–25% of carbon (as pulverized coal) and carbonized, to give a 10–60 mesh pellet product suitable for fluidized reduction or open-arc electric smelting. In the "ore-carbon pellet" process, a rotary kiln is used, and 25–40% of carbon is used. The product size increases with carbon amount. These pellets may be used for oxide reduction in fixed-bed reactors and buried-arc electric furnaces.—K. E. J.

Principles and Applications of the Rheax Elutriator in the Treatment of Ores. F. Kirnbauer. (*Z. Erz. u. Met.*, 1955, **8**, Apr., 157–161). [In German]. An account is given of a vertical elutriator for sizing and classifying sands down to 0·1 mm. The double-pear-shaped rising current elutriator is stated to show high through-put capacity, very fine cuts, speedy adjustment of size of cut, low wear, and low operating costs. It is used for foundry and building sands (50 tons/hour), and is claimed to be useful for pre-sizing ores and for various dressing operations. Use for direct concentration of heavy ores, e.g. iron ores, is also claimed.—E. C.

Pan Sintering Plant for Iron-Ore Fines: Hessicke Berg- und Hüttenwerke A.G. Installation. K. Grethe and H. Huisken. (*Iron Coal Trades Rev.*, 1955, **171**, Aug. 26, 479–484). The authors describe the layout and operation of a German installation for pan sintering iron ore fines for blast furnace use. Factors controlling sinter quality are considered and the capabilities of the installation are outlined.—G. F.

Sintering Practice at Rouge Plant Utilizes Low Grade Hematite. R. L. Cleveland. (*J. Met.*, 1955, **7**, May, Section 1, 616–618). The Dwight-Lloyd sinter plant at the Rouge works of Ford Motor Co. was designed to sinter blast furnace flue dust, but has been found to give a good quality sinter with 30% of the mix consisting of concentrated low-grade Humboldt hematite. A description is given of the design, layout, and operation of the plant.—G. F.

FUEL—PREPARATION, PROPERTIES, AND USES

A Review of Thermal-Radiation Constants. N. W. Snyder. (*Trans. Amer. Soc. Mech. Eng.*, 1954, **76**, 537–539). The

author discusses the determination and values of the various thermal radiation constants, such as the first and second radiation constants and the Stefan-Boltzmann constant.

An Electrically Calibrated Bomb Calorimeter. A. R. Challoner, H. A. Gundry, and A. R. Meetham. (*Phil. Trans. Roy. Soc.*, Series A, 1955, **247**, Apr. 26, 553–580). After a review of the physical foundations of bomb calorimetry a precision bomb calorimeter is described which can be heated electrically or by combustion.—B. G. B.

Fuel. R. A. Acton Taylor. (*Soc. Chem. Ind., Reports on Progress of Appl. Chem.*, 1954, **39**, 165–180). Atomic energy, solid fuels—including the occurrence of sulphur and of germanium in coal, the constitution of coal and a description of some of the principles under development are reviewed. The shortage of coking coal has caused the iron and steel industry to use coke made from gas coals which tend to contain more sulphur. A section dealing with atmospheric pollution gives particulars of the London smog of 1952 and of the Beaver committee's report. (83 references).—E. E. W.

Flame Research: Inauguration of a New Pulverized-fuel Experimental Furnace in Holland. T. Bishop. (*Iron Coal Trades Rev.*, 1955, **171**, Nov. 18, 1247–1250). The author gives details of the experimental furnace fired by pulverized fuel, recently inaugurated at the International Flame Research Committee's experimental station at Ijmuiden, Holland. The auxiliary coal-preparation plant and high-temperature combustion air preheater are also described, and an outline is given of the flame research so far carried out.—G. F.

On Turbulent Jet Mixing of Two Gases at Constant Temperature. S. I. Pai. (*J. Appl. Mech.*, 1955, **22**, Mar., 41–47). The fundamental equations of both two-dimensional and axially symmetrical turbulent jet mixing of two gases at constant temperatures are derived and discussed and a general method given for their solution.—D. H.

Automatic Control of Gas-Fired Industrial Furnaces in Germany. L. Lawther. (*Iron Coal Trades Rev.*, 1955, **171**, Nov. 18, 1233–1235). The author discusses some of the factors influencing the function of an automatic controller for gas-fired furnaces. Examples are given of systems now in operation in German plants.—G. F.

Some Aspects of Open Hearth Waste Gas Analyser Control. F. P. Hubbell. (*Iron Steel Eng.*, 1955, **32**, Aug., 85–88). The author describes in detail a waste gas control unit of completely new design which provides a control selector for desired oxygen content in the waste gases, recording oxygen and combustible meters for each end of the furnace, necessary sequence timers, and signal lights to indicate analyser standardization.—M. D. J. B.

Radiation Recuperators: Use of High-temperature Flue Gases. F. C. Evans. (*Iron Coal Trades Rev.*, 1955, **171**, Dec. 2, 1345–1348). The author describes the shell, cage, and spiral-tube types of Schack radiation recuperators, indicating their merits and limitations and comparing them with convection recuperators. Some practical applications of radiation recuperators are described, and combined radiation and convection units are discussed.—G. F.

Operation of High-Recovery Regenerative-Type Air Preheaters. II. J. Waitkus. (*Trans. Amer. Soc. Mech. Eng.*, 1954, **76**, 706–714). The operation of high-recovery regenerative type air preheaters is discussed with special emphasis on the effective removal of deposits and the control of metal temperatures to avoid dew-point conditions with consequent corrosion of the heating surfaces.—D. H.

Heat Transfer Between Tubes and a Fluid Flowing Through Them with varying Degrees of Turbulence Due to Entrance Conditions. V. C. Davies and M. Al-Arabi. (*Inst. Mech. Eng., Advance Copy*, 1955, June 30). An electrically heated tube was arranged to give the local as well as the average heat transfer between the tube and water, for both normal and abnormal turbulent conditions. The range of the Reynolds number was from 5000 to 17,000. The inlet end thermal effect and the effect of turbulence were studied and the results correlated by dimensionless groups and compared with the data for air recently obtained by the local method. The hydraulic loss of head due to turbulence was compared with the increase in heat transfer. 12 references.—P. M. C.

Size Computations for Satisfactory Regenerators. O. Jenne. (*Radex Rundschau*, 1955, July, 494–498). [In German]. Advantages of using model laws for assessing relationships between operating conditions and size are outlined. Model laws are computed for hot blast stoves, open-hearth chambers, and Ljungström pre-heaters for boilers. In each case relationships are presented in graph form for easy computation.—E. C.

Heavy Liquid Treatment of Particles in French Washers. L. Pozzetto. (*2nd International Conference on Coal Preparation: Rev. Ind. Min.*, 1955, **36**, Jan. 15, 166–183). Since the war, the use of the heavy medium process, using magnetite, has greatly increased for washing fractions greater than 8–10 or 20 mm. The present situation in France, the reasons for the success of the process and some of the more important results are discussed. The author also describes apparatus in use and discusses the advantages of different types.

Recent Results on Operation of Fines Jigs. M. J. Turpin. (*2nd International Conference on Coal Preparation: Rev. Ind. Min.*, 1955, **36**, Jan. 15, 184–191). After reviewing briefly the essential characteristics of fines jigs, the author gives results of industrial trials on material of the order of 0·5 mm. An efficiency only slightly less than that of heavy media separation is claimed, without the added expense from loss of heavy media.—G. E. D.

Production of Hard Coke from Lignite and Non-coking Coals. III & IV. B. Tejnický and J. Kunc. (*Paliva*, 1955, **35**, (9), 256–260; (10), 297–302). [In Czech]. Experiments with briquettes made from inferior coals are described in detail.—F. F.

The Coke-Oven Industry in the U.S.S.R. W. Far. (*Coke Gas*, 1955, **17**, Oct., 389–396). The history of the industry from 1889 onwards is surveyed. Several modern plants, with up-to-date by-product recovery, were built by foreign companies from 1927–33. Administration was reorganized in 1929. From 1934–40, dependence on foreign plant and technologists was reduced. The construction of 63 new coke-oven batteries with a capacity of 19 million tons of metallurgical coke was planned for 1946–50. Production of hard coke increased from 7,285,000 tons in 1942 to 41,500,000 tons in 1954. Research and literature in the U.S.S.R. are surveyed.

Coke Screening. A. E. Conover. (*Blast Furn. Steel Plant*, 1955, **43**, Nov., 1265–1266). A short review of the difficulties associated with the screening of coke is presented and the empirical nature of the process is stressed.—B. G. B.

An Apparatus for Measuring the Visco-Elastic Properties of Coal in the Course of Carbonization. D. Fitzgerald. (*J. Sci. Instruments*, 1955, **32**, Sept., 359–361). The apparatus allows the strain–time relationship for a briquette on application and removal of a sudden stress to be observed. The construction and possible applications of the apparatus are indicated.—L. D. H.

Tar and Tar Products. D. McNeil and L. J. Wood. (*Soc. Chem. Ind., Reports on Progress of Appl. Chem.*, 1954, **39**, 190–202). There is an increasing use of blends of creosote and pitch as liquid fuels. The high emissivity of liquid fuels enables a considerable increase in furnace output to be achieved in the steel industry compared with the use of gaseous fuels. The consumption of coal-tar fuels also increased. (138 references).—E. E. W.

Quality of Metallurgical Coke. Ch. G. Thibaut. (*IRSID, Centre d'Études Supérieures de la Sidérurgie*, Metz, 1954, *Les Cahiers du Cessid*, No. 25, pp. 78). Methods of study of chemical and physical properties of coke are surveyed. Mechanical properties are mentioned in relation to the various tests, and results of work by IRSID are reported. Coke reactivity and other thermochemical properties are discussed in relation to behaviour in the blast furnace, with particular reference to combustion in the tuyere zone. Results of works trials are given. (153 references).—T. E. D.

The Reactivity of Various Cokes. W. Küntscher, J. Holzhey, and G. Dittrich. (*Neue Hütte*, 1955, **1**, Oct., 6–10). It is claimed that the experimental method described is capable of determining the varying reactivities of different types of coke in relation to temperature and atmospheric conditions.

Structure of Coke II—Physical Properties of Cokes Produced from Various Blended Slacks. K. Inouye and A. Roppongi. (*Fuel*, 1955, **34**, Oct., 471–479). Four different kinds of blast furnace coke were prepared from different blended slacks and their structures examined.—B. G. B.

Heavy-Oil Gas-Producer. Guillon. (*Centre Doc. Sidér., Circ. Inform. Tech.*, 1955, **12**, (9), 1801–1809). The oil is vaporized at a high temperature, and the resulting poor gas is partially oxidized. Practical considerations are examined. Composition of the gas produced is approx. 4% CO_2, 16% CO, 14% H_2, 4% CH_4, 0·6% H_2S, and 61·4% N_2. About 70 gas producers of this type are in satisfactory operation in France. Possible industrial applications are discussed.—T. E. D.

Making Producer Gas a Competitive Fuel. G. W. C. Allan. (*J. West Scotland Iron Steel Inst.*, 1953–54, **61**, 183–197). The author summarizes the theoretical considerations involved in gas producer operation and emphasizes the modern views on gasification. The importance of correct depth of fuel bed is stressed and some results are given of tests with automatic control. Two-stage producers are discussed, and consideration is given to tar deposition and dust removal. A suitable method of gas evaluation in the works is suggested.—L. E. W.

The Cleaning of Open Hearth Slack Gases. L. Silverman. (*Iron Steel Eng.*, 1955, **32**, July, 118–122). This paper describes briefly research carried out at Harvard University on air pollution studies connected with open-hearth furnaces. A continuous slag wool stack gas filter unit is described.

Dust Removal from Cupola Gases. K. Guthmann. (*Giesserei*, 1955, **42**, Sept. 15, 519–524). Analyses are given of outlet gas dust and outlet gases. The centrifugal separator and cloth or sack filters used in dry purification of the gas are described, also experiments with a full-scale separator employing glass-fibre bag filters. Finally wet-washing of the gas and electrostatic separators are described individually. The article is illustrated with diagrams.—R. J. W.

Electrical Gas Cleaning. J. Kelting. (*Technik*, 1955, **10**, Oct., 621–628). Various installations of electro-filter dust extractors are described and their performances discussed.

Progress in Gas Cleaning in the Metallurgical Industry. (*Z. Erz. u. Met.*, 1955, **8**, Mar., 101–117).

Physical Principles of Dust Removal. W. Barth. (101–104). A survey is made of the present state of knowledge of the principles of mechanical, wet, and electrostatic dust removal.

Cleaning of Waste Gases by means of Filters. T. Hansen. (104–106). **Electrical Methods of Gas Cleaning.** W. Möbus. (107–109). **Gas Cleaning by means of Cyclones.** W. Barth. (109–111). **Wet Gas Cleaning, particularly with Venturi Scrubbers.** K. Eichfelder. (111–117). A concise account is given of American experimental and plant practices using the Pease–Anthony Cyclonic Scrubber. Applications include blast furnaces, open hearth furnaces, and calcining kilns.—E. C.

Pressure Loss in the Gas Pipeline Connecting the Chiers Works to the Herserange Power Station and Determination of the Coefficient of Friction λ. Collard. (*Centre Doc. Sidér., Circ. Inform. Tech.*, 1955, **12**, (10), 2001–2004). The pressure in various parts of the system, and the temperature etc. are given, and the method of calculation of λ is shown in full.

Town Gas for the Heat Treatment of Metals. G. A. Peterson. (*Australian Inst. Metals: Australasian Eng.*, 1955, June 7, 56–61). Combustion particulars are given concerning gas supplied by the Australian Gas Light Co. A summary is given of the advantages of gas heating such as cleanliness, ease of control of rate and atmosphere, etc., and the uses of special atmospheres prepared from town gas are discussed. Furnace design and temperature control are also dealt with. (8 references).—P. M. C.

TEMPERATURE MEASUREMENT AND CONTROL

Basic Design Considerations for Electrical Temperature Control. D. T. King. (*Machine Design*, 1955, **27**, Oct., 189–200). The article discusses some of the major factors affecting the design of a temperature-controlled system, and describes some of the more common types of controller and their most suitable applications.—M. A. K.

Direct Measurements of Induction Heating Temperatures with Leeds and Northrup Rayotube Detector. J. L. Garrison. (*Metal Treating*, 1955, **6**, July-Aug., 28–30). The principle and construction of the detector is described, the temperature being indicated on a Speedomax Recorder. The instrument, which focuses the emitted radiation on to a thermopile element, will detect 99% of true temperature within 0·6 s.

REFRACTORY MATERIALS

High Temperature Centrifuge for Separation of the Liquid Phase from Refractories. I. Background Studies. R. E. Birch. (*J. Amer. Ceram. Soc.*, 1955, **38**, Sept., 323–329; **II. Centrifuging Tests.** G. Derge and J. Shegog. 329–330). The first part describes experiments indicating the possibility of separating the liquid phase from refractories. In part 2 is described how a low-melting-point slag was separated from silica brick from an open hearth furnace by centrifuging at 1405° C.—D. L. C. P.

Phase Equilibria in the System CaO–TiO_2–SiO_2. R. C. De Vries, R. Roy, and E. F. Osborn. (*J. Amer. Ceram. Soc.*, 1955, **38**, May, 158–171). The results of an investigation are given. The effect of TiO_2 in blast furnace slags is considered.

Mechanism of Material Transport During Sintering. R. F. Walker. (*J. Amer. Ceram. Soc.*, 1955, **38**, June, 187–197). Possible mechanisms of sintering are considered and available evidence is reviewed.—D. L. C. P.

Plant for the Manufacture of Silica Brick Now in Operation. C. Longenecker. (*Blast Furn. Steel Plant*, 1955, **43**, Nov., 1262–1264). A brief illustrated description of the Leslie plant of Harbison Walker Refractories Co., U.S.A., is given.—B. G. B.

Packing Characteristics of Coke Powders as a Factor in the Manufacture of Carbon Refractories. H. P. S. Murthy and R. Singh. (*J. Sci. Indust. Res.*, 1955, **14B**, Nov., 592–597). Results are given of tests to determine the factors which influence the strengths of carbon refractories.—E. E. W.

Super-Refractory Materials. R. A. Long. (*Metal Progress*, 1955, **68**, Sept., 123–128, 190, 192). Developments in the three major fields of super-refractory materials (ceramics, intermetallics, and refractory elements and alloys) are described and indication of future progress is attempted. Titanium carbide with metal binder, molybdenum silicide and molybdenum are considered to be the most promising recent developments.—B. G. B.

Equipment for Testing the Refractoriness Under Load of Refractory Materials. E. Perez Blanco. (*Inst. Hierro Acero*, 1955, **8**, July-Sept., 370–373). [In Spanish]. In view of the importance of refractories control, a laboratory for the determination of refractoriness under load has been equipped at Aviles. The apparatus consists of a battery of five carbon granule furnaces with a travelling bridge carrying the loading and automatic recording gear. Details of construction are shown, and typical results are given.—P. S.

Super Refractories Give Operators Unique Range of Properties. B. M. Johnson, A. A. Turner, and H. S. Schroeder. (*J. Met.*, 1955, **7**, May, Section 1, 601–607). The authors describe the characteristic properties of " super " refractories, dealing mainly with the silicon carbide, fused alumina, fused mullite, and fusion-cast types. All resist very high temperatures, but are usually employed for their other unique properties. Several examples of their use are given.—G. F.

Physical Characteristics of Titanium Carbide Type Cermets at Elevated Temperatures. F. P. Knudsen, R. E. Moreland, and R. F. Geller. (*J. Amer. Ceram. Soc.*, 1955, **38**, Sept., 312–323). The principal purpose of the investigation reported was to determine the creep behaviour and strength of cermets which may be used in the high temperature areas of aircraft. The influence of the proportion of nickel binder is shown.

Survey of Furnace Availability and Roof Life. (*Amer. Iron Steel Inst., Contrib. Met.*, (45), 1954, Oct.). This survey gives the detailed answers received from 54 open-hearth plants to an A.I.S.I. questionnaire dealing very fully with furnace availability and roof life. The questions are concerned with pre-planning and scheduling of rebuilds and the procedure used, and with the construction, design, and maintenance of the roof. Where appropriate, the answers to the questions are summarized in the introduction.—G. F.

Use of High-alumina Brick in the Single-slag Basic Practice. V. E. Belusko. (*Amer. Inst. Min. Met. Eng., Elec. Furn. Steel Conf. Proc.*, 1954, **12**, 184–192). The author describes work carried out at Electric Steel Foundry Co. to improve the life of roof and lining of a 3-ton furnace melting a variety of steels by the single-slag basic practice. Changes made in roof construction are noted, and experiences with refractories containing 70–80% alumina are discussed. The economics of the changes are outlined.—G. F.

Side Walls and Side-wall Maintenance. J. E. Harrod. (*Amer. Inst. Min. Met. Eng., Elec. Furn. Steel Conf. Proc.*, 1954, **12**, 64–67). The author describes the construction and maintenance of electric furnace side walls and discusses the refractories used. The effect of furnace practice on side wall life is also considered.—G. F.

Maintenance of High-magnesia Refractories in Banks and Bottoms. A. C. Ogan. (*Amer. Inst. Min. Met. Eng., Elec. Furn. Steel Conf. Proc.*, 1954, **12**, 57–63). The author briefly discusses the desirability of high-magnesia hearths for melting high-quality alloy steels, and outlines the problems encountered in maintaining them.—G. F.

For Soda Ash Desulphurising . . . What You Should Know About Forehearth Refractories. R. Carlson and S. F. Carter. (*Mod. Castings Amer. Foundryman*, 1955, **28**, Sept., 56–60).

Details are given of an extensive series of service tests on a wide range of refractory linings which were carried out to find the most suitable material to resist soda ash slags in cupola forehearths. It is concluded that there is no universally suitable refractory but that the choice must depend on the particular operating conditions. With a small forehearth ladle in which large amounts of soda ash were used, the longest lives were obtained with a low-porosity clay brick lining using a special mortar and very tight joints, but the lowest cost per day was achieved with monolithic linings of a clay–graphite plastic mixture. In a larger forehearth with smaller additions of soda ash the cracking tendency of the lining was more important and the lowest cost per day was obtained with a dense low-porosity clay brick lining.—B. C. W.

High Temperature Ceramic Coatings. A. Pechman. (*Indust. Finishing*, 1954, **7**, Dec., 336–345). The author gives an account of the nature and properties of ceramic coatings used to protect metals at temperatures in excess of 1100° F. Practice at the Ryan Aeronautical Co. in applying these coatings is described. Cermets and cermet coatings are also discussed.—A. D. H.

New Refractory Uses for Silicon Nitride Reported. J. F. Collins and R. W. Gerby. (*J. Met.*, 1955, **7**, May, Section 1, 612–615). The mechanical, electrical, thermal, and chemical properties of silicon nitride are described, and possible uses of the material as a refractory are discussed.—G. F.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

European Ironmaking Practices. J. M. Walsh, Jun. (*Reg. Tech. Meet. Amer. Iron Steel Inst.*, 1954, 235–261). The author describes sintering and blast furnace practices in England, Sweden, and Germany, following a tour of these countries. Some of the particular problems in each country, and the methods adopted to overcome them, are outlined. The way in which problems are attacked both individually and co-operatively is discussed.—G. F.

Ironmaking at Appleby-Frodingham. (*Metal Bull.*, 1955, Oct., 11–13). A brief account of blast furnace and ore preparation plant at Appleby-Frodingham is given.—B. G. B.

Special Pig Irons for the Pacific North West. J. P. Walsted. (*U.S. Bur. Mines Rep. Invest.*, 5120, 1955, Apr.). The possible development of a grey foundry iron industry on the North West Coast of the United States is discussed. Details of ores available in the area are given.—B. G. B.

Experience with Hot Blast Valves of Simplified Design. W. Dehne. (*Stahl u. Eisen*, 1955, **75**, Aug. 11, 1027–1029). The development of an earlier suggestion for reducing heat losses from, and the cost of, hot blast valves is described. The new valve is of welded construction which, by eliminating flanges, is simpler in construction and cheaper to produce. The amount of cooling water and thus the heat losses are very much less than with conventional designs.—J. P.

Further Considerations on High-Alumina Blast-Furnace Slag. H. Schrader and P. Mehta. (*Tisco*, 1955, **2**, Oct., 193–206). The authors show how the beneficiation of raw materials resulted in an increase of the alumina content of the slag and discuss this in relation to liquidus data. The efficiency and economics of operation at reduced or increased basicity are considered and the results of fluidity determinations on high-alumina slags in the acid and basic ranges are presented. The effect of titanium dioxide additions on high alumina slags are also dealt with. The authors conclude by considering the blast-furnace metal–slag equilibrium. A number of photomicrographs are included. (19 references).—L. E. W.

Coke Quality and Blast Furnace Operating Practice. W. T. Rogers. (*Iron Steel Eng.*, 1955, **32**, July, 122–125). The author discusses the regression equations which were used to analyse data of five blast furnaces and concludes that variations in blast furnace practice have more influence on performance than variations in coke quality.—M. D. J. B.

Brazilian Charcoal Blast Furnace Practice. R. G. Walker. (*Iron Steel*, 1955, **28**, June, 297–300). The Monlevade plant in Brazil works four charcoal blast furnaces. Brief details of practice are given with special reference to the quality of the charcoal, and comparisons are made with the coke blast furnace and the electric pig iron furnace.—G. F.

Iron and Steel Produced From Pyrrhotite Tailings Opens Up Potential Market. B. G. Hunt and A. Turner. (*J. Met.*, 1955, **7**, Sept., Section 1, 944–947). The authors have successfully produced pig iron from roasted iron sulphide concentrate, and have converted some of the iron into mild steel. The process adopted is outlined, and the analyses and properties of the experimental products are discussed. The economic aspects are considered.—G. F.

Radio-active Isotope Studies of Melting and Tapping in the Blast Furnace. W. Loorz and H. Weber. (*Stahl u. Eisen*, 1955, **75**, Sept. 22, 1241–1243). Radio-phosphorus, in the form of a solid iron–carbon–phosphorus alloy, was placed or injected into the melting zone of a blast furnace and samples taken during subsequent tappings of the furnace. These were examined for their specific activity. The results were not completely unambiguous but gave no cause to doubt that there is no mixing of the iron collecting in the hearth of the furnace.—J. P.

Distribution Equilibrium of Chromium between Molten Pig Iron and Slag. T. Niinomi, Y. Matsushita, and K. Kanamori. (*Tetsu to Hagane*, 1955, **41**, Oct., 1075–1081). [In Japanese]. A study was made of the reduction equilibrium of Cr between molten iron (saturated with C and containing 1% of Cr) and blast-furnace slag, at 1350–1500° C, with slag CaO/SiO_2 ratios of 0·6–1·4, under 1 atm pressure of CO. Oxides of Cr in slag are mainly present as CrO. The apparent partition ratio of slag CrO to Cr in iron decreased with increasing slag basicity, and its logarithm was $\propto 1/T$. Favourable conditions for Cr elimination are therefore: (i) more acidic slags, and (ii) lower temperature.—K. E. J.

Smelting of Iron Ores in the Hot-Blast Cupola. O. Schnyder, E. Lobbecke, and H. L. Schwechheimer. (*Iron Coal Trades Rev.*, 1955, **170**, June 17, 1385–1389). The authors have studied the possibility of using a hot-blast cupola for smelting ore fines and ore–turnings mixtures, and conclude that such a process is feasible. Results of some of the early trials are discussed, and the design and construction of the type of cupola devised are described.—G. F.

Measurement of Metallurgical Equilibria by Thermal Conductivity Gas Analysis. J. W. Evans. (*Brit. J. Appl. Phys.*, 1955, **6**, Oct., 364–365). A description is given of a gas thermal conductivity cell which has been used to measure the high temperature equilibria between metal oxides and $CO–CO_2$ gas mixtures. The calibration and use of the apparatus are described.—E. E. W.

A Laboratory Study of the Sintering Process. E. W. Voice and R. Wild. (*J. Iron Steel Inst.*, 1956, **183**, Aug., 404–410). [This issue].

TREATMENT AND USE OF SLAGS

Researches on Blast-Furnace Slags for Road-Making Purposes in Germany, and the Use of Slags in Bituminous Road Surfacings. W. Lorenz. (*Silicates Indust.*, 1955, **20**, Dec., 461–467; 1956, **21**, Jan., 29–32). Developments covering the period from World War I to the present time are discussed. German Standard Specifications are reviewed.—P. F.

Preparation and Chlorination of Titaniferous Slag from Idaho Ilmenites. A. H. Roberson and L. H. Banning. (*Trans. Amer. Inst. Min. Met. Eng.*, 1955, **203**; *J. Met.*, 1955, **7**, Dec., 1335–1342). Research by the U.S. Bureau of Mines has shown that ilmenite, produced as a by-product of monazite dredging in Idaho, can be smelted in a magnesite-lined arc furnace to produce a commercial quality pig iron and a high-titanium slag which can be chlorinated readily to produce a satisfactory yield of $TiCl_4$. The various steps in the method are described in detail, and results obtained are quoted.—G. F.

Some Aspects of the Use of Crushed Slags. H. Manche. (*Silicates Indust.*, 1955, **20**, Nov., 428–431). The effect of the density of crushed slag cements and of the dimensions of the test specimens on the measured compression strength are considered on the basis of experiments. The strengths are compared with those of other types of aggregates.—P. F.

The Applications of Steelworks Slags for Road Making in Belgium. D. Thoenes. (*Silicates Indust.*, 1955, **20**, Oct., 370–373). Slags used in bitumacadam, tarmacadam, and asphaltic concretes have given very satisfactory results in paving roads and aerodromes, particularly since the publication of Dutch official specifications. These are discussed.—P. F.

The Production and Utilization of Iron Blast-Furnace Slag in the USA. F. Hubbard. (*Silicates Indust.*, 1955, **20**, Oct., 359–367). [In English]. The various forms of utilization of slags, and recent developments are discussed. Over 30 million tons were used in the USA in 1953.—P. F.

PRODUCTION OF STEEL

Society for the Study and Promotion of Iron and Steel Technology. (*Aciers Fins Spec. Franç.*, 1955, Nov., 6–8). S.E.R.S.I.D. was formed in 1954 to study problems involved in improving productivity in steelworks; specific projects are usually undertaken at the request of the Federation, or of an iron and steel company. A number of working parties have already been set up to study particular subjects, and results already achieved include the standardization of blast furnace equipment and improvements in steelworks internal transport and handling facilities.—E. A. C.

The New Ravenscraig Works of Colvilles, Limited: First Stage of Development. (*Iron Coal Trades Rev.*, 1955, **171**, Nov. 11, 1181–1184). **Colvilles Extension: A Year's Work on the Ravenscraig Scheme.** (*Iron Steel*, 1955, **28**, Dec., 647–649). Details are given of the layout and plant of the new Ravenscraig Works of Colvilles Ltd., now under construction. The progress made during the first year is outlined.—G. F.

Use of Metal Production Reserves at the Stalin Metallurgical Works. I. M. Ektov. (*Stal'*, 1955, (2), 99–102). [In Russian]. This is a review by the director of the Stalin integrated steelworks of progress since 1950 and of future plans. Production figures in % of the 1950 values are presented and analysed, the increase being attributed mainly to higher productivity of existing plant. A significant contribution has been made by closer co-ordination of the various operations of the whole works.—S. K.

Steel Technology: Iron and Steel Making. G. Bulle. **Rolling Mill Technology.** H. Sedlaczek. (*Z.V.d.I.*, 1955, **97**, Nov. 1, 1111–1125). This is a broad survey of current trends and likely developments of steel plant over the next thirty years. The subjects singled out for discussion are: sintering and other means of utilization of lean ores, production of coke from inferior coals, changes in conventional blast furnaces, electrical and solid-fuel low-shaft furnaces, oxygen blowing of the open-hearth furnace and pure oxygen furnace, oxygen blown converter, electric furnaces, changes in steel works transport and layout; roll pass design, rolling force and power consumption, and cold strip rolling.—J. G. W.

Mo i Rana A/S Norsk Jernverk. U. Styren. (*Iron Coal Trades Rev.*, 1955, **171**, Oct. 28, 1007–1059). Full details are given of the A/S Norsk Jernverk at Mo i Rana in Northern Norway, in a series of articles under the following main headings: History and development; supply of raw materials; hydro-electric power; situation and layout; soil mechanics and ground work; quay and railway; waterworks plant; pig iron plant; steel plant; rolling mills; and main electrical distribution.—G. F.

The Iron and Steel Industry in the Scunthorpe Area. (*Iron Coal Trades Rev.*, 1955, **171**, Sept. 30, 781–791). A description is given of the plant layout, equipment, and operations of the following major iron and steel works in the Scunthorpe area: Appleby-Frodingham Steel Co.; the steel foundry of Thos. Firth and John Brown Ltd.; John Lysaght's Scunthorpe Works Ltd.; and the Redbourn works of Richard Thomas & Baldwins Ltd.—G. F.

(Presidential Address). K. H. Wright. (*Proc. Staff. Iron Steel Inst.*, 1946–53, **61**, 43–51). A very brief account of some of the activities of B.I.S.R.A. and B.C.I.R.A. is presented. Developments in the Staffordshire steel industry are considered. The Round Oak Steel Works Ltd., and Messrs. Stewarts and Lloyds Ltd., Bilston, are mentioned in this connection.—B. G. B.

Scrap Iron from the Recoverer's Point of View. F. L. Levy. (*Proc. Staff. Iron Steel Inst.*, 1946–53, **61**, 86–94). An account of the activities connected with the recovery of scrap and its subsequent sale to steelworks is presented.—B. G. B.

The Oxygen Steelmaking Process. D. O. Davis. (*Reg. Tech. Meet. Amer. Iron Steel Inst.*, 1955, 37–52; *Iron Steel Eng.*, 1955, **32**, Oct., 90–96). The Dominion Foundries and Steel Ltd., Hamilton, Ontario, uses the "L-D" oxygen top-blowing process. The author gives details of the steelmaking plant and its ancillary units, including the oxygen plant, and describes the steelmaking operation.—G. F.

Top Blow Refining of Steel: Theory and Practice. H. Rellermeyer and T. Kootz. (*Iron Steel*, 1955, **28**, Oct., 486–488). The authors review the theory and practice of steel refining by top-blowing with air, oxygen-enriched air, and oxygen blasts. The main factors considered are the decarburization and dephosphorization reactions, slag formation, and nitrogen content of the blown metal.—G. F.

Residual Stresses in Castings. A. Portevin and J. Pomey. (*Inst. Brit. Found.*, 1955, June 20–24, Paper No. 1120). The methods for revealing and measuring internal stresses and their effects are outlined. Surface hardening, pre-stressing, and the problems of residual stresses in relation to castings are considered. The development in small castings of a pre-stressed state favourable to service conditions is briefly referred to.—B. C. W.

The Use of Histograms for the Study of the Life of Converter Bottoms. Delong. (*Centre Doc. Sidér., Circ. Inform. Tech.*, 1955, **12**, (9), 1787–1799). Results obtained from 18 steelworks during 12 consecutive months are examined. The influence of various methods of construction on bottom life is studied, and also the influence of various working conditions.—T. E. D.

New Exothermic Ferro-chromium Alloy: Trials in Steel Converters. (*Iron Coal Trades Rev.*, 1955, **170**, June 3, 1272). This new exothermic ferro-chromium contains 55–57% Cr and up to 4½% C, and is supplied in the form of small briquettes. It has a high rate of solution and gives a chromium recovery of over 90%.—G. F.

Model Experiments on the Deflection of Flow in the Ports of Siemens-Martin Cold Gas Furnaces. M. Hansen. (*Arch. Eisenhüttenwesen*, 1955, **26**, May, 243–251). Tests were made on a 1/15-scale model at the Reynolds Number of the full-size furnace. The velocity required in the model was only 5 times full-scale, the viscosity of the hot air at full scale being about 3 times as great. The dimensions of the model were varied, and the deflection determined by measurement of direction and velocity at the head outlet. The effects were observed of working without jets, and of working with jets in various positions.—A. C.

Calculation of the Strength of O.H. Furnace Roofs. N. P. Kublanov. (*Stal'*, 1955, (3), 218–223). [In Russian]. The generally used method of calculating thrust and compression stresses in O.H. roofs is criticised and a new method is developed. Although this is based on the assumption that the cold roof behaves as an elastic solid arch it gives a considerably more accurate picture of stress distribution. The calculated locations of failure are near the back and front walls, which agrees well with observations on chrome–magnesite roofs. The value of the stresses is least for cold roofs with the ratio of rise to span in the range 1/6–1/4, a conclusion probably applicable also to hot roofs.—S. K.

Rammed Ports and Front Walls in Open Hearth Furnaces. V. N. Litvichko. (*Stal'*, 1946, **6**, (11–12), 697). [In Russian]. Ports and front walls in a basic open hearth furnace rammed with a mixture of chrome–magnesite (17% Cr_2O_3) 10% iron turnings and milk of lime (to achieve required consistency) withstood 120–140 heats without repairs, against 50–60 heats by magnesite brick.—V. G.

Production Control of Quality Steels. R. W. Graham. (*Iron Steel Eng.*, 1955, **32**, July, 125–128). This paper considers the present day steelmaking problem from the point of view of the operator who is responsible for quality as well as for plant economics. The quality control methods in operation at the Duquesne Works of United States Steel Corp. are described.—M. D. J. B.

Speeding Open Hearth Charging: Some Practical Hints. M. D. J. Brisby and W. O. Pendray. (*Iron Steel*, 1955, **28**, Aug., 403–404). Following operational research studies in a number of steelworks, the authors put forward a number of general suggestions for improving the efficiency of charging the O.H. furnace. The factors considered include scrap quality and storage, and the correct supervision of the supply system.—G. F.

Decarburization of Iron with Hydrogen. L. Špaček. (*Hutnické Listy*, 1955, **10**, (9), 549–550). [In Czech]. A mathematical discussion of the dependence of the rate of decarburization on the partial pressure of hydrogen and the temperature.

Hydrogen in Steelmaking. H. Epstein, J. H. Walsh, and T. B. King. (Amer. Iron Steel Inst.: *Indust. Heating*, 1954, **21**, Dec., 2472–2478; 1955, **22**, Feb., 320–332; May, 990–994). The solubility of hydrogen in iron and liquid steel is discussed. The variation in the hydrogen content of the bath during basic O.H. and electric steelmaking was followed using a new design of sampling device.—A. D. H.

The Problem of Iron Oxide Fume. A Pilot Plant for Precipitation of Iron Oxide Dust. P. Leroy and L. Septier. (*Publ. Inst. Rech. Sid.*, Series A, 1955, July, (102), 37). The pilot plant at the Mondeville works of the Société Métallurgique de Normandie, for the precipitation of iron oxides, silica, etc.

from the fumes given off during the pre-refining of Thomas iron in the ladle by injecting pure oxygen, is described. The plant can purify 17,000 m³ of fume given off during treatment of 40 tons of iron. The larger dust particles are first removed by a centrifugal precipitator. The smaller particles are removed in a cyclone, after saturation with water vapour and passage through a special type of venturi. Operating data are given.—T. E. D.

Electric Arc Furnaces. F. D. Gunton and O. S. Steele. (*Elect. Rev.*, 1955, **157**, Sept. 30, 639–644). A general outline description is given of the characteristics of the Héroult-type metallurgical arc furnace, points considered being the automatic current control system, load characteristics, the use of reactance, and the transformer and switchgear.—L. D. H.

Process Measurements Lead to Control of Melting Practices. H. H. Johnson and G. A. Fisher. (*J. Met.*, 1955, **7**, Dec., 1316–1320). The authors describe the quality control techniques employed in electric-furnace melting of carbon steels at the Sharon Works of National Malleable and Steel Castings Co. They refer particularly to accurate weighing of the charge, recording the oxygen used, control of carbon and manganese, furnace operation, and quality of the product.—G. F.

Melting Process Offers Higher Quality Superalloys. W. W. Dyrkacz. (*Iron Age*, 1955, **176**, Oct. 27, 75–77). The process of arc melting under vacuum is being used as a production process and the technique and results are described. Electrodes are cast from an air-melt of the required alloy and these are re-melted under vacuum by arc melting in a water-cooled copper crucible. 2000-lb ingots have been made. Degasification is similar to induction vacuum melting but metal cleanliness is claimed to be superior, due to the high temperatures. The resulting metal has improved workability and tensile properties and little segregation, and may prove valuable for jet-engine applications.—D. L. C. P.

Application of Special Elements to Electric Furnace Steels. A. J. Scheid, jun., and W. J. Mathews. (*Amer. Inst. Min. Met. Eng., Elec. Furn. Steel Conf. Proc.*, 1954, **12**, 174–181). The authors discuss the following special aspects of electric steelmaking: hydrogen elimination by oxygen, nitrogen, and argon; special deoxidation by aluminium, calcium, magnesium, manganese, sodium, titanium, zirconium, and rare earths; carbide stabilization by columbium and tantalum; increasing hardenability by aluminium and boron additions; and increasing machinability by lead, phosphorus, selenium, and sulphur additions. The most effective procedure and the necessary basic steps in melting are outlined.—G. F.

Acid Electric Steelmaking Practice. C. C. Wissmann. (*Amer. Inst. Min. Met. Eng., Elec. Furn. Steel Conf. Proc.*, 1954, **12**, 108–121). The author reviews acid electric steelmaking practice with special reference to the aspects of oxidation. Oxidation during meltdown is first dealt with, and the inter-relationships of slag composition, hydrogen absorption, and melting variables are discussed. Data on oxidation during the boil are next given, and finally the effects of oxygen injection are considered.—G. F.

The Melting of Austenitic Chromium–Nickel Alloy Steels from Scrap Using Pure Oxygen in the Basic Electric Arc Furnace. R. Peters. (*Neue Hütte*, 1955, **1**, Oct., 11–19). Tests carried out in the 500-kg basic electric furnace of the Steel Research Institute, Hennigsdorf, confirmed statements in the literature regarding high yield of alloy. In order to attain the high temperature required, a very high refining speed was adopted, and the heat of exothermic reactions was used to the full by injecting all the oxygen at once, and by adding ferrosilicon to increase the silicon content before refining.—L. J. L.

Synthetic Carbon and Electro-Graphite. F. Aldebert. (*Elektrowärme-Techn.*, 1955, **6**, July-Aug., 143–149). The production, properties, and uses of carbon and synthetic graphite for furnace electrodes are discussed. The use of synthetic graphite, made at high temperatures from a sintered mass of coke and organic binders, includes blast-furnace linings and electric-furnace electrodes.—P. F.

Let's Make Basic Steel. J. P. Holt. (*Mod. Castings Amer. Foundryman*, 1955, **28**, Aug., 33–37). The economics of converting from acid to basic electric-furnace practice are outlined in general terms, and the differences in furnace operation which will arise are reviewed. The oxidizing and reducing reactions which may occur in a basic slag are considered from the point of view of removing phosphorus, sulphur, silicon, carbon, manganese, and chromium from the bath. The fundamental rules for successful operation of a basic-lined furnace are brought out and emphasized in the discussion.

Vacuum Furnaces Will Make Better Steels. (*Iron Steel Eng.*, 1955, **32**, July, 136–140). This article describes a new 1000-lb vacuum furnace installation at Carboloy Dept. of G.E.C. Semi-continuous operation is provided by interlocks through which the crucible can be charged, the alloying elements altered, and the ingots removed without breaking the vacuum in the main chamber.—M. D. J. B.

Alnico Magnets for New Meter. H. Wilkinson. (*Canad. Metals*, 1955, **18**, Oct., 42–46). The production of Alnico magnets is described.—B. G. B.

New Developments in the Production of the Alloy Alni. A. M. Maslov. (*Liteĭnoe Proizvodstvo*, 1955, (4), 26–27). [In Russian]. An account is given of the technology of the production of an alloy (61·0–55·5% Fe, 13·0–15·0% Al, 23·0–26·0% Ni, 3·0–3·5% Cu, 0·05–0·08% C, P + S < 0·03, Si < 0·20 and Mn < 0·20) used for permanent magnets and, more briefly, of the methods of casting.—S. K.

The Role of Slag Composition in Open Hearth Desulphurization and Oxidation. H. L. Bishop, T. B. King, and N. J. Grant. (*Blast Furn. Steel Plant*, 1955, **43**, Oct., 1148–1150, 1186; Nov., 1259–1261). A review of physico-chemical factors, affecting the influence of O.H. slag composition on desulphurization and oxidation of steel, is presented. It is shown how it is difficult to choose a slag which will be an efficient desulphurizer while maintaining a rapid rate of carbon elimination. (12 references).—B. G. B.

Removal of Copper from Iron–Copper–Carbon Melts by the Use of Sodium Sulphide Slags. F. C. Langenberg, R. W. Lindsay, and D. P. Robertson. (*Blast Furn. Steel Plant*, 1955, **43**, Oct., 1142–1147). The results of tests carried out on a laboratory scale in graphite crucibles showed that copper could be readily removed from the melt by the use of sodium-sulphide slags. Sulphur is also removed from the metal and also manganese. The copper is rapidly removed from the metal.—B. G. B.

Phase Composition of Some Calcium Oxide–Chromium Oxide Slags With Special Reference to the Solubility in Water of Their Calcium Oxide Component. D. S. Belyankin and V. V. Lapin. (*Doklady Akad., Nauk, SSSR*, 1953, **91**, (4), 911–914). [In Russian]. Phase composition of two slags rich in chromium and calcium oxide was investigated using microscopic, X-ray, and analytical methods. It was found that about 15% of lime can be extracted by treatment with water. Experimental results are described in some detail.—V. G.

Thermodynamics of Metal Sulphides, With Special Reference to Equilibria Between Sulphides and Oxides. T. Rosenqvist. (*Tidsskr. Kjemi, Bergvesen Met.*, 1955, **15**, (6), 96–101). [In Norwegian]. Details are given of methods for determining the free energy required if sulphides are to be formed from elements or if sulphur is to be dissolved in molten metal. Examples are also given to show how sulphide–oxide equilibria can be calculated using such thermodynamic data.—G. G. K.

Ladle Lining and Practice for Stainless Steel. H. R. Lewis. (*Amer. Inst. Min. Met. Eng., Elec. Furn. Steel Conf. Proc.*, 1954, **12**, 204–205). The author describes methods and materials used in foundry ladle practice for stainless and other high-alloy steels at Allegheny Ludlum Steel Corporation.

Report of the Steel Casting Sub-Committee. (*Centre Doc. Sidér., Circ. Inform. Tech.*, 1955, **12**, (10), 1969–1971). A study of the effect of casting practice on the properties of unkilled and killed steels is briefly outlined.—T. E. D.

Hydrodynamics of Fused Metals. L. I. Fantalov. (*Liteĭnoe Proizvodstvo*, 1955, (5), 31–32). [In Russian]. Papers presented at a recent conference, dealing with a wide variety of problems in the flow of liquid steel and other metals, are summarized.—S. K.

Continuous Casting of Steel in Austria: New Plant at Breitenfeld. F. Leitner. (*Iron Coal Trades Rev.*, 1955, **171**, Nov. 18, 1241–1244). Details are given of the continuous casting unit which has been in production at the Breitenfeld steelworks in Austria since 1953. Operating results are given, and the effects of casting conditions on metal structure and quality are discussed.—G. F.

Rail Transport of Hot Ingots. (*Aciers Fins Spec. Franç.*, 1955, Nov., 17–19). A brief account is given of tests being carried out by the French Railways on the transport of hot ingots by rail. The insulated cases and also the special insulated covered trucks developed for this purpose are described, together with the results of some of the tests. A

51-ton ingot at a temperature of 750° C has been delivered at its destination 5 h later, at a temperature of 690° C.—E. A. C.

Steel Casting in Ingot Moulds. W. Kilian and W. Kaiser. (*Giessereitechn.*, 1955, **1**, July, 116–120). The literature on ingot casting is briefly surveyed. Experiments at VEB Foundry, Copitz, are described, results are discussed, and suggestions for mould materials, protective coatings, design, and prevention of flaws are made.—L. J. L.

Continuous Casting. J. S. Smart. (*Metal Progress*, 1955, **68**, Oct., 117–125). A review is made of the practical application of continuous casting. Experience gained with aluminium and copper alloys has helped to develop continuous casting of steel to a practical production technique. Examples of commercial plants are described.—B. G. B.

Continuous Casting of High-Alloy Steels: Production Plant at Jacob Holtzer, Unieux, France. (*Iron Coal Trades Rev.*, 1955, **170**, May 27, 1221–1225). The Jacob Holtzer Works has developed a technique for continuously casting austenitic and other high-alloy steels. Details are given of the plant and its operation, and some of the difficulties overcome in the early experiments are described.—G. F.

On the Inverted-V Segregated Zone of Large Carbon Steel Ingots. M. Kawai. (*Tetsu to Hagane*, 1955, **41**, Aug., 854–851; Oct., 1090–1092). [In Japanese]. In order to reduce defects in large forgings, a study has been made of a 20-ton ingot, by sulphur prints, examination of microstructure, etc., and the existence of a large number of segregated "faces" as well as lines of segregation in the inverted-V zone is shown. The structure of the following zones in the ingot is explained: columnar crystals (exterior), dendritic crystals (layer adjacent to the last), free crystals (centre), sedimentary crystals (bottom), V segregation (in the upper portion), inverted-V segregation (surrounding the last), and top segregation zones.

The Structure of Steel Ingots and its Alteration By Annealing, Forging and Rolling. B. Matuschka. (*Inst. Hierro Acero, Special Number*, 1955, **8**, Oct., 496–519). [In Spanish]. The characteristic features occurring in carbon and alloy steel ingots are illustrated and discussed. The effects of hot working, with particular reference to homogenizing the structure, are described.—P. S.

PRODUCTION OF FERRO-ALLOYS

The Smelting of Manganese Ores. Ferro-Manganese Requirements in the Spanish Steel Industry. B. Chavarri. (*Inst. Hierro Acero*, 1955, **8**, July-Sept., 385–397). [In Spanish]. The methods employed for the production of ferromanganese are discussed. Native ore production is insufficient to meet the increasing demands of industry for ferromanganese and imports are necessary. It is suggested that methods of increasing the national production should be studied.—P. S.

Alumino-thermic Production of Ferro-Chromium and Ferro-Tungsten. D. Horta Machado. (*Bol. Assoc. Brasil Met.*, 1954, **10**, Oct., 385–389). [In Portuguese]. The manufacture of ferro-chromium and ferro-tungsten by the Orosco process (patented in Brazil) is described. Liquid aluminium is poured on to the pulverized oxides and stirred to give pellets containing both ore and aluminium. The thermal reaction in the pellets is initiated by means of a peroxide slag, an oxy-acetylene torch, and an oxygen lance. An average analysis of the ferro-chromium is 0·05% C, 0·020% P, 1·5% Si, 48·0% Cr; ferro-tungsten 0·05% C, 0·025% P, 1·0% Si, 70% W. The process is compared favourably with the electro-thermic method.—P. S.

Determination of the Melting Range of Commercial Ferro Alloys. H. Brendecke and F. Pawlek. (*Arch. Eisenhüttenwesen*, 1955, **26**, Mar., 125–126). The melting range of a number of ferro alloys, e.g. ferrochrome, silicochrome, ferro titanium, ferro vanadium, and ferro niobium—tantalum, was determined by using fireclay crucibles and argon as protective atmosphere. The buttons obtained were metallographically examined.—T. G.

FOUNDRY PRACTICE

Ideas on the Classification of Iron–Carbon Cast Alloys. A. Wittmoser. (*Giesserei*, 1955, **42**, Oct. 13, 573–580). In view of the introduction of cast Fe–C alloys with spheroidal graphite formation, the various methods of classification are reviewed. (44 references). The author criticizes the various methods and suggests classification under the following main headings:—cast steel, temper cast (i.e. malleable cast iron) and grey cast. The economic advantages of this are discussed.

New Developments in Foundry Furnaces and Ovens. R. R. Maierhofer. (*Engineer Foundryman*, 1955, **20**, Sept., 52–57). The costs and advantages of electricity, coal gas, producer gas, oil, coke, coal, and electricity are discussed. Foundry furnaces are described and the economics of operation are given.—A. D. H.

Mechanisation of Foundries in the USSR. B. Horníček. (*Slévárenství*, 1955, **3**, (10), 317–321). [In Czech]. A report is given of a visit to the USSR, dealing mainly with mechanization, layout and efficiency in grey and malleable cast iron founding.—P. F.

Light Iron Castings and the New Die Pressing Process. R. S. M. Jeffrey. (*Amer. Foundryman*, 1955, **27**, May, 88–95). The growth of the light iron castings industry in Great Britain is outlined and some of the work carried out by B.C.I.R.A. which is of direct interest to this branch of the foundry industry is reviewed. The die pressing process developed for the production of cast iron gutters is described and discussed.

Do's and Don'ts of Fan Connections. W. E. Tracy. (*Amer. Foundryman*, 1955, **27**, June, 74–77). The factors to be taken into account in designing exhaust systems are briefly discussed.

Foundry Production Reserves. N. D. Titov. (*Liteĭnoe Proizvodstvo*, 1955, (5), 21–25). [In Russian]. Measures taken to increase foundry output to deal with simultaneous increases in both the total weight and the variety of castings required are described. By various measures the cost of casting was decreased by 6·5–8·5%.—S. K.

Nomogram for Fairly-hot Non-Alloyed Iron Cast in Ordinary Dry-sand Moulds. Sv. Thegel. (*Inst. Brit. Found.*, 1955, June 20–24, Paper No. 1132). The construction of a nomogram between thickness of casting, composition, and hardness for fairly-hot unalloyed cast iron is described. The relationships established from 150 test-bars are between section thickness (C + ¼ Si), and (H − 30P) where C, Si, and P are the percentages of carbon, silicon, and phosphorus respectively and H is the Brinell hardness. The practical application of the nomogram is demonstrated.—B. C. W.

Quality Control in a Large Foundry in the Automotive Industry. R. Baggio. (*Inst. Brit. Found.*, 1955, June 20–24, Paper No. 1124). A detailed description is given of the quality control methods used in the Fiat foundries in Turin as they are applied to grey iron, malleable iron, and light alloy castings.—B. C. W.

Evaluation of Casting Processes. H. Brown. (*Inst. Brit. Found.*, 1955, June 20–24, Paper No. 1119). The advantages of castings are briefly discussed and the merits of the various casting processes are considered with particular emphasis on the disadvantages and limitations of some of the so-called precision casting methods. The necessity of improving existing processes rather than developing more casting methods is stressed.—B. C. W.

Melting in a Basic-Lined Cupola. L. I. Levi. (*Liteĭnoe Proizvodstvo*, 1955, (4), 3–8). [In Russian]. After consideration of the thermodynamics of desulphurization and dephosphorization in general and in basic-lined cupolas in particular, the results of trials with such cupolas under various conditions are presented.—S. K.

Better Castings Achieved by Melting Cast Irons Under Basic Slags. A. G. L. Lewis. (*Engineer Foundryman*, 1955, **20**, May, 51–53, 62). The cupola melting of cast iron under basic slags is shown to be advantageous in the production of "Meehanite," when high ash–low calorific value cokes are used.—A. D. H.

In the Ladle . . . Five Ways to Desulphurise. D. E. Parsons and S. L. Gertsman. (*Amer. Foundryman*, 1955, **27**, June, 60–65). Results are presented to show the effects of ladle or tap-stream additions of from 15 to 40 lb/tn of calcium carbide, calcium cyanamide, lime, soda ash, or caustic soda on the sulphur content, mechanical properties, nitrogen content, and metallographic structure of grey cast iron. For all materials the reduction in sulphur content was proportional to the amount added, efficiency decreasing in the order: caustic soda, soda ash, calcium carbide, calcium cyanamide, lime. The nitrogen content of heats desulphurized with calcium cyanamide tended to increase to 0·02–0·023% regardless of initial content whereas with the other additions the final contents were of the order of 0·008%. Ladle additions of large amounts of caustic soda or soda ash resulted in loss of silicon from the bath.—B. C. W.

The Burning Actions in the Cupola Furnace. W. von Preen. (*Giesserei*, 1955, **42**, Aug. 4, 419–420). The burning actions,

in particular the carbon, oxygen, CO, CO_2 equilibria, are first considered on theoretical grounds. Laboratory investigations to substantiate the theoretical work are described. The main reaction is not the direct burning of carbon to CO_2, but involves the formation of CO at an intermediate stage.

The Structure and Mechanical Properties of White Irons. W. J. Williams. (*Metallurgia*, 1955, **52**, Sept., 129–134). The manner in which changes in the structure of white irons can influence their mechanical properties is discussed.—B. G. B.

The Production of Pyroferal Castings. Z. Eminger. (*Slévárenství*, 1955, **3**, (10), 309–317). [In Czech]. The technology of making Fe–Al alloy castings is discussed in detail with special reference to Czechoslovak practice.—P. F.

Low-Expansion Cast Iron. H. Brown. (*Machine Design*, 1955, **27**, June, 175–177). Properties and design characteristics of a nickel cast iron capable of holding precision dimensions under local heating conditions.—M. A. K.

High-Frequency Furnaces and Their Use in Foundries. J. C. M. Broglio. (*Bol. Assoc. Brasil. Met.*, 1954, **10**, Oct., 347–349). [In Portuguese]. This article is a condensation of the one given at the 10th annual congress of the Brazilian Society of Metals. In addition to giving a general review of these furnaces, the author shows that they are advantageous for the production of high-quality castings.—P. S.

Value and Interpretation of Mechanical Tests on Grey Irons. A. Roos. (*Rev. Gén. Mécan.*, 1955, **39**, Jan., 1–5; July, 243–246). Methods used to study the mechanical properties of grey irons are first considered. Extensometric and pendulum methods for measuring the modulus of elasticity are described and the influence of the iron composition on elasticity is explained. The relationship between Brinell hardness and the combined carbon in the iron and modulus of elasticity is discussed. The relationship between the hardness of grey irons and their resistance to wear is also considered.—B. G. B.

Comparative Study of Melting Furnaces Used in Iron Foundries. B. Marincek. (*Inst. Brit. Found.*, 1955, June 20–24, Paper No. 1126). The trends in coke and electricity costs are considered and it is pointed out that it may soon become more economical to use electric furnaces rather than coke- or coal-fired units for melting cast iron. The factors influencing the quality of cast iron and the economic and technical advantages and disadvantages of the cold-blast and hot-blast cupolas, the electric-arc furnace, and the electric-induction furnace are discussed. Although the capital cost for an induction melting furnace are high it may be economical under special conditions.—B. C. W.

Theory of Nodular Graphite Formation in Ductile Cast Iron. P. H. Anderson. (*Amer. Found. Soc., Preprint*, No. 21, 1955). Previous work on the structure and mechanism of formation of graphite nodules is briefly discussed and a new theory for nodule formation is proposed. It is suggested that carbon precipitates from the undercooled liquid as a cloud of minute platelets which behave as flat carbon molecules and agglomerate to give spherical masses, which then behave as mesoforms or liquid crystals. At or just below the eutectic temperature, the mesoforms acquire crystal regularity in three dimensions. Some X-ray diffraction results are presented to show that numerous imperfections exist in the graphite nodules after solidification and that these may be decreased by prolonged annealing just below the eutectic temperature.

Progress Report: Fluidisation–Injection Process for Desulphurising and Upgrading Cast Iron. G. P. Dahm, H. C. Barnes, and C. E. Bieniosek. (*Amer. Found. Soc., Preprint*, No. 23, 1955). The process of desulphurizing cast iron by injecting calcium carbide in a stream of dry nitrogen into the molten metal is described and discussed, and its advantages are briefly outlined. The production of nodular or ' upgraded ' iron by injecting a mixture of a cerium-bearing magnesium ferrosilicon alloy, excess silicon, and calcium carbide is considered, and some results obtained using this technique are presented. The inoculation injection may be preceded by desulphurizing with calcium carbide, which gives a saving in the amount of alloy required for inoculation.—B. C. W.

On the Metallurgy of High Quality Cast Irons with Compact or Spheroidal Graphite Formation. E. Piwowarsky and E. G. Nickel. (*Giesserei*, 1955, **42**, July 21, 385–392; Aug. 4, 412–419). Overheating of the melt and deoxidation is first considered as a method of producing high-quality cast irons. Next the use of basic melting together with overheating the melt is discussed. The degasification of cast-iron melts may be effected with purging gases. High vacuum may be used for gas purification of cast-iron melts. Finally the use of reaction mixtures and metallic materials for extensive deoxidation is described, the aim being a compact graphite distribution in the cast iron. The thermodynamics and chemical reactions likely to proceed in each method are described. (31 references).

Graphite Formation in Grey Cast Irons and Related Alloys. H. Morrogh. (*Brit. C.I. Res. Assoc. J. Res. Dev.*, 1955, **5**, June, 655–673). A comprehensive review of the existing knowledge of graphite formation in grey irons is presented. (48 references).—B. G. B.

Study of Several Spheroidal Graphite Austenitic Cast Irons. J. Grilliat. (*Rev. Nickel*, 1955, **21**, Jan.-Mar., 16–21; Apr.-June, 41–45). The properties of a number of nickel-containing austenitic cast irons with spheroidal graphite are compared with each other and with cast irons containing lamellar graphite, ferrito-pearlitic and pearlitic cast irons, and steel. Composition and structure of the cast samples are discussed, together with examination of the influence of added elements on the structure. Mechanical properties, physical properties, corrosion resistance, and properties when hot are compared and discussed.—T. E. D.

Spheroidal Cast Iron. J. Creydt. (*Engineer Foundryman*, 1955, **20**, July, 48–53). The production and properties of S.G. iron are described and compared with normal irons. In South Africa, the main application of the material is in the manufacture of rolls.—A. D. H.

Recent Developments regarding Nodular Cast Iron. J. Kol. (*Metalen*, 1955, **10**, Aug. 31, 333–339). [In Dutch]. Summaries are given of papers by various Continental authors on the subject of nodular cast iron read at the 1954 Foundry Congress held at Florence. They concern the analysis of the pig iron destined for making nodular cast iron, the resultant improvements to be expected, and the role the latter material can play for use in machine parts instead of steel.—F. R. H.

The Scope of Permanent Moulds in Casting Grey and Malleable Cast Irons. F. Naumann. (*Slévárenství*, 1955, **3**, (12), 385–387). [In Czech]. Recent experiences and developments in the German Democratic Republic are discussed.—P. F.

Effects of Some Melting Variables on Properties of Malleable Iron. G. E. Kempka and R. W. Heine. (*Amer. Found. Soc., Preprint*, No. 64, 1955). Experimental results obtained in an investigation into the effects of melting variables on the mechanical properties and annealability of malleable iron are presented in detail. Among the variables studied were water vapour and nitrogen in the furnace atmosphere, and the sulphur content of the metal. A quality index based on the area under the stress/log strain curve is defined and this is discussed in relation to the variables affecting the tensile properties of malleable irons.—B. C. W.

Hot Working of Cast Iron. H. Poetter. (*Technik*, 1955, **10**, Nov., 675–680). The literature of this subject is reviewed. It is shown that hypo-eutectic whiteheart irons, malleable and nodular irons can be rolled, pressed, forged, and extruded, that thus the consequence of working the strength of the cast irons is increased many times, and the ductility and toughness improved. The paper contains details of optimum working conditions and of effects of composition. Reference is also made to the process developed in the Soviet Union for the manufacture of wide sheet directly from molten cast iron which is poured into the roll gap.—J. G. W.

Recommended Melting Practice for Small Heats. N. J. Grant. (*Precision Met. Mold.*, 1955, **13**, Nov., 32–33, 71–73; Dec., 51–52). Part I discusses in outline the general and specific problems involved in the melting of small batches for investment casting. In Part II the author gives the recommended practice for melting 5–20-lb batches of 18/8 Ti stainless steel by high-frequency induction heating.—D. H.

Use of Basic Ladle Linings in the Foundry. K. T. Apgar. (*Amer. Inst. Min. Met. Eng., Elec. Furn. Steel Conf. Proc.*, 1954, **12**, 203). The method of installing and maintaining basic ladle linings at Taylor-Wharton Iron and Steel Co., New Jersey, is outlined.—G. F.

Carbon and Alloy Steel Castings: Production at Head Wrightson and Company, Ltd. (*Iron Steel*, 1955, **28**, May, 189–194; June, 291–295). Details are given of the layout and operation of the Thornaby works of Head Wrightson and Co., Ltd., producing carbon and alloy steel castings. The melting facilities are first described, followed by details of the sand recovery and distribution system. The semi-mechanized and other moulding areas are then considered, and the finishing end, incorporating heat-treatment furnaces, is described. Technical control exercised by the metallurgical, methods,

and maintenance departments is discussed, and finally typical examples of production are detailed.—G. F.

The Avesta 'Layer' Method of Determining the Pouring Speeds for Steels. S. H. C. Forslund. (*Acciaio Inossid.*, 1955, **22**, Mar.-June, 45–68). [In Italian]. This paper describes a method developed by the author for determining the pouring speed of steels for castings. The movement of the metal in the surface layers is studied and the effects of pouring from the ladle top and through a bottom hole are examined in detail. The 'layer' method consists in establishing the speed of rise in the mould by imagining a grid thrown over the mould which separates off portions of equal volume. A knowledge of the speed of metal rise in the mould determines the optimum pouring speed.—M. D. J. B.

Bottom-Pour Ladle Practice. A. W. Fastabend. (*Amer. Foundryman*, 1955, **27**, Apr., 43–45). The development of a double-shell lining for ladles which are used in conjunction with basic electric furnaces is described and costs are given for the various linings which have been used. With double linings there are no skulls or metal losses and, for a given furnace-tapping temperature, the mould-pouring temperature increased by 70° F (40° C).—B. C. W.

British Cast Steels. J. Lomas. (*Canad. Min. J.*, 1955, **76**, Aug., 54–57). British production is concentrated on a limited number of comparatively simple and standard steels, capable of fulfilling most steel casting purposes. Types of steels for castings, their basic compositions, and their principal and characteristic applications are tabulated, and some are discussed.—T. E. D.

Sand–Resin Cores, Moulds Produced Automatically on Versatile Core Blower. W. G. Patton. (*Iron Age*, 1955, **176**, July 7, 91–93). Cores weighing up to 20 lb can be formed and cured in a single operation at from 50 to 90 cycles per hour, in the new machine described.—D. L. C. P.

The Foundry Industry in Australia. A. W. Silvester. (*Inst. Brit. Found.*, 1955, June 20–24, Paper No. 1135). The foundry industry in Australia is reviewed and its relation to the structure and economy of the country is described. The basic material and power resources of Australia are also summarized and the future of the foundry industry is considered.—B. C. W.

On Surface Defects in Thin-walled Grey Iron Castings. L. Hütter. (*Giesserei*, 1955, **42**, Nov. 10, 636–638). Observations in the works indicated that the quality of the moulding sand used influenced the formation of surface defects in thin-walled castings. A series of experiments were carried out which confirmed this and showed that the water content and compression strength of the moulding sand were the important factors, whilst the change in gas permeability had little effect. The practical consequences of this are discussed.—R. J. W.

Formation of Shrinkage Defects in Grey Iron Castings: Influence of the Mould. J. Gittus. (*Iron Steel*, 1955, **28**, July, 331–335; Aug., 387–390). A phenomenon observed with grey iron is that dry sand moulded castings contain appreciably smaller shrinkage cavities than green sand moulded castings. By techniques involving length-change measurements, changing mould-cavity dimensions during solidification, and sand temperature measurements, the author shows that the phenomenon is due to the high rigidity of the dried mould causing initial inward sand expansion, reducing casting expansion and the size of the cavity.—G. F.

On the Kinetics of Development of Graphite Structure in Cast Iron. K. P. Bunin and I. V. Salli. (*Doklady Akad. Nauk SSSR*, 1952, **83**, (6), 841–842). [In Russian]. Graphitization of iron during vacuum annealing was investigated. It is concluded that the rate-determining stage in the process is the migration of iron atoms with which the nucleation and growth of graphite inclusions are connected.—V. G.

REHEATING FURNACES AND SOAKING PITS

Continuous Furnace Heated by Low-Calorific Gas. B. R. Imenitov. (*Stal'*, 1955, (3), 274–278). [In Russian]. Continuous-furnace design for working on poor gas is discussed. Best results are at present being obtained with blast-furnace-gas fired types having ceramic and metal recuperators for air and gas, respectively, and injector-burners. For gas with C.V. of 1900–2200 kg.cal/m^3 only the air requires a recuperator. Much remains to be done on the improvement of injection-burner design, increasing the range of automatic control to include gases of 2200 kg.cal/m^3, and metal recuperators must be produced for heating air to 600° C by combustion-products at 1100° C.—S. K.

Towards Greater Economies in the Performance of Soaking Pits having Refractory Recuperators. J. V. Skopal. (*Hutník*, (Prague), 1955, **5**, (12), 354–358). [In Czech]. On the basis of a performance analysis a greater thermal efficiency of refractory recuperators used in Czechoslovakia is shown to be attainable if recuperator lining materials of higher quality were used, the diameter of the recuperator tubes was changed, and carborundum tubes were introduced.—P. F.

Billet-Mill Soaking Pits at the Works of Samuel Fox & Company. (*Iron Coal Trades Rev.*, 1955, **171**, Dec. 9, 1415–1418). A description is given of the modern soaking pit installation at the Stocksbridge Works of Samuel Fox and Co., Ltd., handling 6000 tons per week in eleven pits. Details are given of the soaking-pit building, producer gas plant, ingot charging and discharging, heating chamber, burner and pre-combustion chamber, soaking-pit cover, control room and instrumentation.—G. F.

Work Coils for Induction Heating. D. Warburton-Brown. (*Machinery*, 1955, **87**, Nov. 18, 1181–1186; Nov. 25, 1239–1244). Various types of coils and their applications are considered. Multi-turn, copper tube coils are widely used for industrial purposes. Flattened tubing may be employed to increase the number of turns in a given length and rectangular, pancake, beehive, tunnel, and combined internal and external coils may be designed in addition to cylindrical types. The disadvantage of copper for certain operations is discussed. In the second part, the adjustment of the heat pattern, coil supports, and the provision of cooling are considered.—M. A. K.

Detroit Steel Corporation's Multiple-Fueled Soaking Pits. F. C. McGough. (*Iron Steel Eng.*, 1955, **32**, July, 55–62). A detailed description is given of the new circular type soaking pits at Detroit Steel Corp., the method of firing, recuperation of combustion air and the selection and application of control equipment. The author shows that it is practical to use low calorific value mixed gas and preheated combustion air and that it is possible to transfer to a higher thermal gas without adversely affecting mill operations.—M. D. J. B.

Application of Small Industrial Ovens. H. Gehnrich. (*Indust. Heating*, 1955, **22**, May, 1019–1030). The application of small batch-type ovens for core drying, tempering etc. which are heated by forced convection are described.—A. D. H.

Giant Field Stress Relieving Furnace for Penstock Sections. (*Indust. Heating*, 1955, **22**, July, 1372–1376). A hexagonal-shaped furnace 30 ft wide × 45 ft long × 30 ft high which was used to stress-relieve large welded assemblies weighing up to 120 tons on the site of a large dam building project is described.—A. D. H.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

Heat Treatment Furnaces in Rolled-Product Manufacture. B. V. Malyshev. (*Stal'*, 1955, (3), 251–261). [In Russian]. Recent designs of heat-treatment furnaces for rolled products of carbon and alloy steels are considered with special reference to those in which oxidation and decarburization are prevented. Furnaces dealt with include those for normalizing, bright annealing or hardening followed by tempering, for hardening and bright annealing stainless steel sheet; for bright isothermal annealing and for isothermal soaking, normalization and sorbitization of rails.—S. K.

Investigations on the Effect of Abrupt Temperature Changes on the Surface Finish of Steel. W. Rädeker. (*Stahl u. Eisen*, 1955, **75**, Sept. 22, 1252–1260). The influence of repeated quenching of specimens of a range of steels from temperatures varying from 300° to 1000° C into water and of intermittent heating of one face of cooled specimens on the formation of surface cracks and crazing has been studied. The results are interpreted as due to tensile stresses arising from temperature variations.—J. P.

Electric Furnace Design For Steel Heat Treatment. A. G. Wallbank. (*Australian Inst. Metals: Australasian Eng.*, 1955, Aug. 8, 57–69). The paper outlines the fundamental requirements of an electric furnace and the design steps which should be taken to meet them. A statement of the needs of a particular process is followed by an extensive discussion of the mechanical, electrical, heat, and chemical factors which must be taken into account in the final design.—P. M. C.

Oil Fired Heat Treatment Furnaces. H. R. Goode. (*Australian Inst. Metals: Australasian Eng.*, 1955, Sept. 7, 54–60).

The main principles of the generation of heat by the combustion of oil fuel, the transfer of heat within the furnace, furnace efficiency, and the constructional features of furnaces having a bearing on these factors are examined in a qualitative sense. In addition, oil burner equipment and some of the more important characteristics of oil fuels are included.

On the Distortion of Tool Steels. A. Adachi and S. Yamada. (*Techn. Rep. Osaka Univ.*, 1955, **5**, Mar., 161–168). The distortion following heat treatment of carbon tool steel, high C–Cr–Mo–W and high-speed steel, was measured on slotted ring specimens. Warpage was least on martempered specimens.—J. G. W.

Cast High Alloys For Heat Treating Equipment. (*Metal Treating*, 1954, **5**, May-June, 6–7, 18). The compositions of fourteen standard American heat-resisting cast alloys are tabulated. These may be classified in three groups: iron–chromium alloys with up to 30% chromium and less than 7% nickel, offering excellent resistance to oxidation and sulphurous atmospheres but with only moderate hot strength; iron–chromium–nickel alloys with 18 to 32% chromium, and 8 to 22% nickel (chromium content higher than nickel) which have greater high temperature strength than the previous group; alloys with from 23 to 68% nickel and 10 to 23% chromium which are fully austenitic and maintain excellent hot strength up to 2000° F but are unsuitable in high sulphur-bearing atmospheres. Alloy selection and the design of equipment is also discussed.—P. M. C.

New Shaker-Hearth Furnace Increases Production. F. C. Schaefer. (*Metal Treating*, 1954, **5**, Sept.-Oct., 4–5). A description is given of an American Gas Furnace Co. shaker machine with a continuous automatic quenching tank. Complete control of the furnace atmosphere is possible. The equipment is primarily used to harden small parts, requiring an exposure to hardening temperature for only three or four minutes, at rates up to 350 pounds per hour.—P. M. C.

The Economics of Anhydrous Ammonia For Industrial Applications. A. E. Wastie. (*Metal Treating*, 1954, **5**, Sept.-Oct., 12–13, 42). Ammonia dissociators and storage systems required for various heat-treating operations are described and cost analyses are presented. The advantages and disadvantages of anhydrous ammonia storage methods are discussed.

Heat Treating Stainless Steels. W. E. McFee. (*Steel*, 1955, **137**, Aug. 8, 70–72; Aug. 15, 158–162). A review is given of modern methods of heat treatment for various types of stainless steel. The effects are illustrated and typical problems explained. Annealing and hardening treatments are specified.

How to Obtain High Quality Carburized Cases. H. E. Mansfield. (*Mat. Methods*, 1955, **41**, Jan., 134–137). Practical notes are presented relating to temperature uniformity and control, atmospheres, cooling and hardening, which aim to show how uniform results can be obtained in gas carburizing processes by relatively simple procedures.—P. M. C.

Change to Gas-Carburizing Improves Piston Pins. R. E. Haislip. (*Mat. Methods*, 1955, **41**, June, 140–143). A short account is given of a new gas-carburizing furnace at the Chrysler Corp., installed for the continuous treatment of piston pins. The new procedure has replaced the previous pack hardening process.—P. M. C.

Spheroidizing Improves Ball-bearing Steel. (*Metalworking Prod.*, 1955, **99**, Sept. 30, 1682–1683). Five batch type furnace units, together with exothermic and endothermic protective gas plant, have been installed by G. W. B. Furnaces Ltd. in the works of Tubes Ltd. at Kirby Muxloes. This installation is for the spheroidizing of steel for ball races and ball bearings and similar applications.—M. A. K.

Salt Baths: Casehardening, Isothermal, and Sulfinuz Processes. F. D. Waterfall. (*Iron Steel*, 1955, **28**, Nov., 507–510). The author considers thermal treatment salt baths of three main types; baths for casehardening, neutral salt-baths for isothermal heat treatment, and "Sulfinuz" salt baths, based on cyanide and sulphur compounds, which impregnate the surface with nitrogen and sulphur and improve wear resistance without necessarily increasing surface hardness. Examples of the different plants, their operation, and the results obtained, are discussed.—G. F.

Gas Purge for Consistent Carburizing Quality. P. M. Unterweiser. (*Iron Age*, 1955, **176**, July 28, 72–74). The method of gas carburizing at a job shop in New York is described. Furnaces are fitted with a Leeds and Northrup "Microcarb" atmosphere control.—D. L. C. P.

Exchange of Experiences in Flame Hardening, 1955. (*Metalloberfläche*, 1955, **9**, Aug., B118–B121). A summary is given of subjects discussed at a meeting in Essen concerned with flame hardening. Part A dealt with basic principles, and part B was concerned with the application of flame-hardening to repairs.—L. D. H.

Batch Carbon Restoration Annealing of Bar Stock. H. W. Callahan. (*Metal Treating*, 1955, **6**, Mar.-Apr., 10, 12, 14). Details are given of a radiant tube, controlled-atmosphere, car bottom type furnace designed and built by Surface Combustion Corporation for the Jones & Laughlin Steel Corporation. Equipped with endothermic and exothermic gas generators, the furnace is used for annealing and normalizing hot rolled bar stock with simultaneous restoration of carbon to the decarburized surface. Details of the heating and atmosphere control cycles are given.—P. M. C.

Inductive Heating Improves Quality of Automotive Replacement Parts. O. W. Noeske. (*Indust. Heating*, 1955, **22**, Aug., 1572–1574, 1726). The surface hardening of shafts and king-pins by induction heating is briefly described.—A. D. H.

The Carbonitriding Process. H. N. Ipsen. (*Indust. Heating*, 1955, **22**, Mar., 508–512, 520). The advantages of carbonitriding in which steel is simultaneously carburized and nitrided by heating in an atmosphere containing hydrocarbons and ammonia are discussed. Furnace design, practice, and methods of control are described.—A. D. H.

Case-Hardening Automobile Parts, and Nitriding Without Hardness Increase. E. Cindric. (*Bol. Assoc. Brasil Met.*, 1954, **10**, Oct., 401–415). [In Portuguese]. Methods of heat-treatment to give the correct microstructure for case-carburizing, case-carburizing methods, and final heat-treatments are discussed in relation to the production of automobile parts. Plain carbon, low alloy, and austenitic steels, also cast and malleable irons for engine parts may be nitrided at 550–580° C in a salt bath for 20 to 90 min to develop increased wear resistance rather than an increased skin hardness.—P. S.

Nitriding of Magnesium Cast Iron. V. D. Yakhnina. (*Liteĭnoe Proizvodstvo*, 1955, (4), 23–25). [In Russian]. The nitriding process, and its effects on the properties of magnesium-inoculated cast iron and a structural steel are compared. Nitriding was carried out at 550, 600, 650, 700, and 750° C, a specimen of each of the materials being treated simultaneously. Determinations were made of resistance to corrosion in water for seven days, porosity (with Walker's reagent), brittleness of the nitrided layer, the extent of cracking and the micro-hardness. Non-uniformity of hardness of the nitrided layer on the magnesium iron is attributed to local variations in magnesium concentration, and pre-nitriding annealing of such irons is therefore recommended.—S. K.

Softening with Time Dependence of Cold-drawn Steel, II. High Carbon Steel. G. Mima. (*Techn. Rep. Osaka Univ.*, 1955, **5**, Mar., 139–148). Isothermal annealing curves were obtained for cold drawn 0·58 and 0·65% C wires, initially possessing lamellar pearlitic, spheroidized, or sorbitic structures. Discontinuities in the annealing curves of elongation, yield strength, and ultimate tensile stress, are interpreted in terms of heterogeneity of deformation of the constituent phases.—J. G. W.

Heat Treating Dies in Salt Bath Furnaces Aids Production of Fastenings at H. M. Harper Co. K. G. Hookanson. (*Indust. Heating*, 1955, **22**, June, 1153A–1158). Electric salt bath furnaces are used in a U.S. works for the heat treatment of dies for hot and cold forming and thread rolling. The layout of the plant and heat treatment practice are described briefly.

Heat Treating in Neutral Atmospheres. A. W. Frank. (*Indust. Heating*, 1955, **22**, Apr., 760–762). The hardening of small springs and the annealing of stainless steel welded assemblies in atmospheres made by cracking ammonia are described.—A. D. H.

Principles and Applications of Step Quenching (Martempering). R. F. Harvey. (*Metal Treating*, 1955, **6**, May-June, 6–8, 10–11). The essential features of the S curve or T.T.T. diagram are described, and the martempering process in which the specimen is quenched in salt to equalize its temperature at or just above the M_S point followed by air cooling is discussed in detail. The many benefits of hardening by this method are described.—P. M. C.

FORGING, STAMPING, DRAWING, AND PRESSING

Production of Gas Turbine Blades by Precision Forging.

E. B. Wells. (*Machinery*, 1955, **87**, Dec. 2, 1292–1297). Precision forging is being used extensively by Utica Drop Forge and Tool Corporation, U.S.A. to make gas turbine blades varying in length from 2 in. to 12 in. to close tolerances. Vacuum furnaces are used for melting most of the alloys used. Forging is carried out on mechanical presses or drop hammers, and 'Chambersburg Impactors' have recently been successfully introduced.—M. A. K.

Special Upset-Forging Line Makes 140 Axle Shafts an Hour. P. Trippe. (*Metalworking Prod.*, 1955, **99**, Nov. 25, 1979–1983). Axle shafts are produced at Garringtons Ltd., Bromsgrove, on a very compact line comprising two electrical upsetters, a friction screw press and a trimming press. Only three operators are required and output is 140 components per h.—M. A. K.

Forging at Walter Somers, Limited, Halesowen: Manufacture of Crankshafts and Die-blocks. (*Iron Coal Trades Rev.*, 1955, **171**, Dec. 9, 1423–1425). Details are given of the main forge, machine shop, and die-block production shop at the Haywood Forge of Walter Somers, Ltd., Halesowen.—G. F.

Some Observations On The Mechanical Working of Metals. A. R. E. Singer and C. S. Ball. (*J. B'ham. Met. Soc.*, 1954, Golden Jubilee Issue, 153–168). The approach to research in metallurgy, and the manner in which the approach can affect the progress of research is discussed briefly. As an example, surface friction in relation to metal working processes is discussed. Bowden and Tabor's fundamental studies of friction are reviewed, and the role of friction in metal working processes is dealt with by considering recent work and views on rolling, extrusion, and cold drawing. (17 references).

Continuous Press Forging: Process for Automatic Production of Crankshafts. W. G. Davis. (*Iron Steel*, 1955, **28**, Oct., 477–479). Automobile crankshafts are now being produced practically automatically by a continuous press forging process at the Chrysler Corporation's forge plant at Detroit, Michigan. The main features are three 6000-ton mechanical forging presses, each served by a rotary billet-heating furnace, and the automatic heat-treating and tempering furnaces. Details of the plant and processes are given.—G. F.

Continuous Drawing of Cold Finished Bars. W. J. Prochak. (*Iron Steel Eng.*, 1955, **32**, July, 95–98). This paper describes the design of a production line with maximum speed and economy for the output of $\frac{1}{4}$ to $\frac{5}{8}$ in. cold finished bars, involving rounds, hexagons, flats, and squares.—M. D. J. B.

Apply Correct Clearance and Speed When Drawing Stainless Steels. S. R. Cope. (*Metalworking Prod.*, 1955, **99**, Oct. 28, 1831–1833). The author describes methods of drawing stainless steel, nickel, and high nickel alloys for both normal and deep-drawing. Bending and forming dies, cemented-carbide die parts, suitable lubricants and optimum press speeds are discussed.—M. A. K.

On the Profile of Tube Drawing Dies (II) Experiments with Diescope and Soft Steel Dies. S. Yazawa and K. Sato. (*J. Mech. Lab.*, 1955, **9**, July, 141–146). By examining surface of experimental tube-sinking dies before and after drawing by a reflection method, conclusions are drawn about the effect of die profile on wall pressure and die wear. The optimum profile consisted of a straight-tapered entry portion followed by a curved one.—J. G. W.

Drawing Failures in Extruded Shells. H. J. Pessl. (*Metal Progress*, 1955, **68**, Aug. 1, 80–81). The origin of defective extruded shells was traced to the increase in diameter of the punch caused by the stresses during drawing.—B. G. B.

Investigation of the Mechanics of Wire Drawing. J. G. Wistreich. (*Inst. Mech. Eng., Advance Copy*, 1955, Apr. 1, 13–24). An experimental study of the relations between external forces and process parameters in wire drawing is described. Using a split die, drawing force, mean die pressure, and mean coefficient of friction were measured. Weaknesses in all existing wire drawing theories are revealed, and semi-empirical formulæ for the forces are devised. A simple relation between tool-stock configuration and non-homogeneity of deformation was discovered. There was no correlation between die pressure and coefficient of friction. (21 references).—P. M. C.

Austenitic Stainless Steel Wire Drawing. E. Segre. (*Acciaio Inossid.*, 1955, **22**, July-Aug., 105–120). [In Italian]. The author gives a comprehensive review of stainless steel wire drawing techniques for both medium and very fine wire. The effects of heat treatment on the mechanical working properties are examined. Examples of industrial uses of stainless steel wire are given.—M. D. J. B.

ROLLING-MILL PRACTICE

Uniskan Roll-reduces in One Pass. A. T. Taylor. (*Metalworking Prod.*, 1955, **99**, Oct. 21, 1793–1795). "Uniskanning" is a coined word. The article describes possibilities and limitations of this process, derived from experience in applying the method to a variety of materials.—M. A. K.

Principles of Rolling Speed Calculation. Z. Wusatowski. (*Metallurgie*, 1955, **5**, Sept., 282–289). Calculations of rolling speed for rectangular and normal cross-sections, and of the diameter of rollers, are described.—L. J. L.

Considerations in Applying Rectifiers as a Power Supply for Hot Strip Mills. G. M. Zins and E. J. Cham. (*Trans. Amer. Inst. Elect. Eng.*, 1954, **73**, Part II, 65–70). Advantages of ignition rectifiers as main power supplies are discussed. These include high efficiency, lower initial and maintenance costs, and simplification of controls.—L. D. H.

Stress and Strain in Rolling Mill Housings. J. D. Keller. (*Blast Furn. Steel Plant*, 1955, **43**, Oct., 1131–1138; Nov., 1250–1258). The use of rubber models to indicate stress distribution in rolling mill housings is first considered. Methods of calculating the stress in housings are described with examples.—B. G. B.

Craven 40½-in. Centre Heavy-duty Roll Turning Lathe. (*Machinery*, 1955, **87**, Oct. 7, 847–848). The article describes a lathe designed for heavy, high-speed turning operations with cemented-carbide or Stellite cutting tools. Work up to 30 ft long and 64 in. diameter can be accommodated.—M. A. K.

Discussion on the Choice of Rolling Mills for the Production of Plane Profiles with Reference to Market Requirements. A. C. Sao Thiago Filho *et al.* (*Bol. Assoc. Brasil Met.*, 1955, **11**, Apr., 237–265). [In Portuguese]. This topic was discussed at the tenth scientific conference of the Brazilian Society of Metals. A paper on this subject is preceded by an introduction and followed by a general discussion.—P. S.

Recording Techniques for Rolling Mill Operation Studies. E. A. Chard, W. W. Hastings, and D. F. Nettell. (*J. Iron Steel Inst.*, 1956, **183**, Aug., 368–375). [This issue].

The Time Characteristics of the Slabbing Mill. H. G. Jones, D. T. Steer, and P. D. Dickerson. (*J. Iron Steel Inst.*, 1956, **183**, Aug., 375–386). [This issue].

Note on the Principles Governing the Design of Ingots for High Output in the Slabbing Mill. H. G. Jones, P. D. Dickerson, and D. T. Steer. (*J. Iron Steel Inst.*, 1956, **183**, Aug., 386–389). [This issue].

Improvement of Guides for Rolled Products. A. F. Minaev and N. P. Lebednyatseva. (*Stal'*, 1955, (2), 146–149). [In Russian]. Improved designs of rolling-mill guides for rounded sections are described and their performances at the Stalin metallurgical works are compared with those of previously used types.—S. K.

Modern Speciality Steel Mill. H. G. De Young. (*Canad. Metals*, 1955, **18**, Sept., 28–31; Oct., 24–28). An account of 4 recent developments at the Atlas Steel Corporation are discussed. These are the automatic scarfing machine, the continuous casting process, the Sendzimir hot planetary mill and the electrolytic salt descaling plant.—B. G. B.

The Inductive Measurement of Thickness and Tension in Strip Mills. P. K. Herman. (*AEG Progress*, 1955, (2), 140–144). A detailed review of the inductive method for continuous measurement of thickness, tension, and roll pressure in strip mills is presented. Examples of the design of instruments are given and the sources of error and their elimination discussed.—B. G. B.

New Steel Tube and Pipe Mill Offers Variety of Specialty Products. P. M. Unterweiser. (*Iron Age*, 1955, **176**, Aug. 18, 75–78). A new tube and pipe making installation is described; based on the 'Calmas' process, it produces wall thicknesses from $\frac{1}{4}$ to 3 in., diameters $5\frac{1}{2}$ to 16 in., lengths up to 80 ft. All products are seamless and can be made on large or small quantity basis. The process hot-pierces, elongates, and equalizes cast steel ingots in a wide variety of analyses.

Steel Supplier Has Modern Plant for Customer Service. A. Q. Smith. (*Indust. Heating*, 1955, **22**, Apr., 770–782). The annealing, rolling, and tube drawing plant of the Korhumel Steel and Aluminium Co., Illinois, is described.

Metallurgical Aspects of the Production of Copper Tubes. O. Jore. (*Tidsskr. Kjemi, Bergvesen Met.*, 1955, **15**, (4), 60–70). [In Norwegian]. Sections deal with modern methods

of ingot casting, refining, problems due to SO_2, casting procedure and mould cooling, continuous casting, extrusion and metal flow rates, tube rolling, drawing and the associated deformation mechanism.—G. G. K.

Modern Rolling-Mill Plants and Their Drive. H. Drück. (*A.E.G. Progress*, 1955, (2), 42–47). A survey is made of the main trend of development in the production of rolled steel, in rolling mill machinery and electric drives which have contributed to the rebuilding of the German steel industry.

Friction of Steel Slabs on a Roller Table under Varying Physical Conditions. S. K. Dean and M. A. Kilburn. (*Inst. Mech. Eng., Advance Copy*, 1955, Oct. 14). Values of the coefficient of friction between steel slabs and rollers have been determined from acceleration tests on a model roller table. The effective coefficient of friction was found to be independent of slab temperature in the range 700–1100° C, and with hot slabs was affected less by slab weight and roller speed than with cold slabs. Mean valves for the friction coefficient were 0·20 cold, and 0·29 hot. Grit-blasting the slabs, heavy scaling, and the presence of mill scale and water are factors which all tended to increase the friction in the case of hot slabs.—P. M. C.

Control of a Stationary Shearing-Line Guillotine for Automobile Body Sheet. W. Sussebach and B. Dahm. (*A.E.G. Progress*, 1955, (2), 105–109). A rapid acting and accurate control equipment for a shearing line with a stationary guillotine is described. An accuracy of $\pm$ 0·059 in. has been achieved irrespective of the lengths being cut with average feed velocities of up to 246 ft/min according to length.—B. G. B.

Machines for Processing Medium and Heavy Plates. F. W. Zürcher. (*Stahl u. Eisen*, 1955, **75**, Sept. 8, 1182–1188). The development of shearing, slitting, straightening and bending machines and presses for medium and heavy plates is discussed and illustrated with particular reference to the working conditions in production and consumer plants. Suggestions for future development are given.—J. P.

A Control System for a Flying Tube Saw. W. Naffin. (*A.E.G. Progress*, 1955, (2), 98–104). The co-ordination of drive and control of a flying saw of the type used in parting off long lengths of rolled and welded tube is explained with the aid of circuit diagrams and oscillograms. The type of circuit described is equally applicable to rotary saws and shears.

Automatically Operated Flying Shears in Sheet Rolling Mills. D. Hladík. (*Hutnické Listy*, 1955, **10**, (11), 675–676). [In Czech]. The design of automatic flying shears and the thermionic accessories of recent Czechoslovak manufacture are described.—P. F.

Control Amplifiers in Rolling Mills. E. Nagel. (*A.E.G. Progress*, 1955, (2), 127–134). The special properties of magnetic and electronic amplifiers in the circuits normally used in rolling mills are compared after a brief discussion of amplifier technique. A number of simplified amplifier circuits as used in rolling mills are explained.—B. G. B.

Electrical Remote Indication and Automatic Screw-Down Control in Steel Mills. R. Dehmlow. (*A.E.G. Progress*, 1955, (2), 144–148). Selsyn and Servo type mechanisms for remote indication of the position of moving parts are described with examples.—B. G. B.

Position Control of Electrical Screwdown Drives. D. B. Manwaring. (*J. Iron Steel Inst.*, 1956, **183**, Aug., 410–415). [This issue].

MACHINERY FOR IRON AND STEEL PLANT

Maintenance of Steelworks Cranes and Locomotives. A. G. Thomson. (*Mech. Handling*, 1955, **42**, Aug., 449–450). The system of planned maintenance used by the management of Steel, Peech and Tozer, Rotherham, designed to prevent and reduce the occurrence of breakdowns of steelworks cranes and locomotives is briefly described.—D. H.

Instrumentation in the Ferrous and Non-Ferrous Industries. S. S. Carlisle, G. P. Clay, and J. B. C. Robinson. (*J. B'ham. Met. Soc.*, 1954, Golden Jubilee Issue, 243–260). Instrumentation is considered in two parts; on the one hand, process measurement and control, on the other, gauging, inspection and testing. Instruments for the measurement of gas and liquid flow, temperature, and gas analysis are described, and the application of automatic control to furnaces is outlined. Gauging, inspection, and testing is discussed with reference to thickness and width measurement of strip, and quality inspection and testing of coatings etc. by a variety of well established physical techniques. The advances made possible by the use of electronics are emphasized. (10 references).

The Use of Blast-Furnace Slag for Water Purification. N. Metelenko and A. Strel'nikova. (*Stal'*, 1955, (2), 183). [In Russian]. The successful use of granulated acid blast-furnace slag for water filtration at a metallurgical works is described. The slag-particle sizes ranged from 1·5–3·0 mm, the depth of the filtering layer being 800 mm.—S. K.

State of Development of Modern Machine Tools with Respect to the Tasks of Maintenance Shops. F. Oswald. (*Stahl u. Eisen*, 1955, **75**, Sept. 8, 1149–1162). Increased output and quality from steelworks has had a marked influence on the requirements to be met by the maintenance department and thus on its needs for machine tools of higher working rate and greater size. Modern development in such tools is reviewed and copiously illustrated.—J. P.

Development and Technical Status of Single Purpose Machine Tools for Iron and Steel Works. H. G. Rohs. (*Stahl u. Eisen*, 1955, **75**, Sept. 8, 1162–1170). The possibilities of improving the performance of single purpose machine tools are discussed in respect of better cutting and grinding tools and automatic working. Modern tools discussed include those for processing blooms and semi-finished products, roll-turning lathes and roll-grinding machines. The adapting of bloom processing machines to the tasks required, e.g. mechanization of charging, fixing and centring operations, is described. Recent roll shaping and grinding machines are discussed and illustrated.

Plant Treats Own Water Supply, Saves $100,000 Yearly. (*Iron Age*, 1955, **176**, July 28, 63–65). The plant for purifying 11 million gallons per day of turbid lake water for steelworks use is described. Water is treated with lime, clay, and alum before passing through settling tanks.—D. L. C. P.

Teleprinter Technique for Automatically Recording and Analysing Data: Application to the Steel Industry. D. F. Nettell. (*Iron Coal Trades Rev.*, 1955, **170**, June 17, 1409–1411). The author describes how the ordinary teleprinter may be used as a rapid operational or instrument recording machine in industry. Methods of analysing the tape are outlined, and some of the applications of the technique are mentioned.—G. F.

WELDING AND FLAME-CUTTING

Resistance Welding and Post Heat Treatment of Steel Stud Projection Welds. E. V. Beatson, E. Mitchell, and L. N. Sayer. (*Brit. Welding J.*, 1956, **3**, Jan., 10–19). The development of a tempering technique to give a joint with satisfactory metallurgical properties is described. A modified EN 15 steel, containing approximately 0·3% C and 0·15% S, gives cracks in the heat-affected zone if allowed to quench directly to low temperatures at which martensite forms. An isothermal post-heating technique, which allows the steel to transform at elevated temperatures to safer metallurgical structures, has been developed.—U. E.

Possibilities and Limits of Glueing of Metals. E. Rubo. (*Schweissen u. Schneiden*, 1954, **6**, Special Issue, 106–116). The author discusses a new method of joining metals using a synthetic resin which age-hardens. The method has been applied to joining sheets of steel, aluminium alloy, and two different types of metal. The testing of glued metal bonds is discussed.—U. E.

The Applicability of Alternating Current for Deep Penetration Welding. H. Neumann. (*Schweissen u. Schneiden*, 1955, **7**, Oct., 415–423).

What has to be Observed when Gas Welding Cast Iron? H. Reininger. (*Schweissen u. Schneiden*, 1955, **7**, Oct., 424–429). An investigation was made on welding of cast iron. It is shown that preheating is of considerable importance for obtaining a satisfactory weld. A number of micrographs are given which show the effect of welding and preheat on the structure of grey cast iron. The welding of cast iron and steel is briefly compared.—U. E.

Some Interesting Welding Investigations. W. P. Campbell and M. J. Nolan. (*Canad. Metals*, 1955, **18**, July, 42–45; Aug., 47–50). The case history of a number of failures of welded parts are reported and the reason for failure explained.

Choose the Right Arc Welding Electrode. L. K. Stringham. (*Steel*, 1955, **137**, Oct. 10, 138–141). The principles of arc welding are outlined, and a chart is given which enables the best type of electrode to be chosen from the required properties of the weld and the conditions of use.—D. L. C. P.

The Basis and Application of Low Temperature Welding. G. M. Blanc and J. W. Kloppers. (*Lastechn.*, 1955, **10**, Aug.,

120–126). [In Dutch]. This is a description of a method of welding large work pieces, the join being effected by formation of a binary metal alloy at the surface of the parts to be welded between the additional material and a very thin layer of the original metal resulting from diffusion of particles in the surface layer of the latter and the plastified additional material. Microphotos of such welds and illustrations of practical welded repairs are shown.—F. R. H.

Hydrogen in Mild Steel Weld Deposits. N. Christensen and R. Rose. (*Brit. Welding J.*, 1955, **2**, Dec., 550–558). The formation of internal microcracks has been studied in single-run deposits from eleven brands of continental electrodes. Hydrogen contents have been determined in water-quenched samples of weld metal by vacuum extraction at 650° C. It was found that cracking occurs in a temperature range below 250° C, and loss of hydrogen which occurred during slow cooling is not a main factor in the prevention of cracking.

Methods for Measuring the Hydrogen Content of Weld Metal. P. D. Blake. (*Brit. Welding J.*, 1955, **2**, Dec., 558–561). A description is given of the methods used in the laboratories of Murex Welding Processes Ltd., for measuring the diffusible and residual hydrogen contents of ferrous weld metal. The two values can be determined separately by collecting the diffusible hydrogen under mercury at room temperature and subsequently extracting the residual hydrogen by vacuum heating. Alternatively the total hydrogen may be determined in a single step by vacuum heating.—U. E.

Types of Failure Related to Stress and Temperature. F. Hebrant, H. Louis, W. Soete, and A. Vinckier. (*Rev. Soudure*, 1955, **11**, (3), 152–173). [In French]. The authors discuss various types of failure from the practical design point of view. The principal factors considered are the quality of the steel and weld metal, the stress, the temperature at which the structure is designed to operate, the thickness of the metal parts, and the speed at which the stresses are applied.

Study of Mechanical Relaxation of Residual Welding Stresses under Static Load and Fatigue. F. Hebrant, H. Louis, W. Soete, and A. Vinckier. (*Rev. Soudure*, 1955, **11**, (3), 139–151). [In French]. A detailed description is given of the research techniques adopted to measure residual stresses in spliced and butt welds under static and dynamic loading.—M. D. J. B.

Gas Welding Processes—Brazing, Cutting, Surface Treatment and Heat Treatment. H. von Hofe and H. Killing. (*Rev. Soudure*, 1955, **11**, (3), 126–136). [In French]. The authors make a comprehensive review of brazing techniques; cutting processes; surface treatment, including metallizing and cleaning; and of heating and heat treatment techniques, including normalizing and straightening of buckled plates.

Acetylene in Heavy Industry. E. J. H. Elsworth. (*Rev. Soudure*, 1955, **11**, (3), 117–125). [In French]. The author describes industrial techniques which make use of mixtures of oxygen and acetylene in the flame. Despite the introduction of new gases which are now used with oxygen, acetylene remains the best in many cases encountered in heavy industry; particularly for heavy cutting, gouging, scarfing, powder cutting and cleaning, surface tempering, and flame cleaning.

Self-Adjusting Welding Arcs: Drift in Power Source Output and Electrode Feed Rate. J. C. Needham. (*Brit. Welding J.*, 1955, **2**, Nov., 506–513). The effect of drift both of power source and of electrode feed rate on arc equilibrium in self-adjusting arcs is discussed and methods of combating drift are suggested.—U. E.

Stress-Corrosion Cracking of Welded Joints. R. N. Parkins. (*Brit. Welding J.*, 1955, **2**, Nov., 495–501). The problem of stress corrosion cracking of welded joints and its prevention by means of stress-relieving treatments are discussed.—U. E.

Cold Pressure Welding. J. Reinhold. (*Soudage Techn. Connexes*, 1955, **9**, July-Aug., 169–176). Welding is carried out by means of localized pressure at ordinary temperatures. It is applied particularly to aluminium, copper, and their alloys.—T. E. D.

Viewpoints on the Linde Method of Stress Relieving. R. Gunnert. (*Soudage Techn. Connexes*, 1955, **9**, July-Aug., 177–183). The theory of the Linde method of low temperature stress relieving is examined from the point of view of relieving residual stress in welds. Experimental results and published literature are considered. In conclusion it is seriously doubted whether the method does what it is alleged to do. Comments by H. R. Pufahl of Union Carbide International Co. are included in an appendix.—T. E. D.

Inert-Gas Shielded-Arc Welding in the Gas-Turbine Industry. F. G. C. Sandiford, R. T. Weatherstone, J. E. Hooper, K. H. McDowell, and L. Camidge. (*Brit. Welding J.*, 1955, **2**, Oct., 443–455). A review is given of the shortcomings of materials, tooling technique, and equipment in the field of inert-gas shielded-arc welding.—U. E.

Some Electrical Aspects of Inert-Gas Shielded-Arc Welding. L. H. Orton and J. C. Needham. (*Brit. Welding J.*, 1955, **2**, Oct., 419–426).

Heat Flow in Argon-Arc Welding. R. L. Apps and D. R. Milner. (*Brit. Welding J.*, 1955, **2**, Oct., 475–485). The heat flow in argon-arc welding without filler metal has been investigated for aluminium, lead, nickel, copper, and Armco iron.—U. E.

Consumable-Electrode Inert-Arc Spot Welding. R. L. Hackman. (*Welding J.*, 1955, **34**, Sept., 839–845). Fields of applications, advantages, and limitations of the process are discussed.—U. E.

New Control System Cuts Scrap Loss on Tube Welding Line. D. C. Fisher. (*Iron Age*, 1955, **176**, Aug. 4, 84–86). A steel conduit manufacturing line at Mahoning Valley Steel Co., Ohio, is described. A new automatic control system measures strip thickness, stores the information while tubing is formed, and sets the current on the induction welding machine accordingly. Line speeds of over 200 ft per min are possible.

Weldability of Cast Steels. H. Thielsch. (*Machine Design*, 1955, **27**, July, 167–171). Welding and heat-treatment procedures and electrode specifications for cast carbon- and low-alloy steels are discussed.—M. A. K.

Weldability of Stainless Steel. H. Thielsch. (*Machine Design*, 1955, **27**, June, 157–164). The article is a design guide to alloy selection, electrode and rod specification, and heat-treatment procedures. Welding of austenitic, and ferritic stainless steels are discussed.—M. A. K.

Multiple Spot Welding by the 'Press Welding' Technique. (*Machinery*, 1955, **87**, Aug. 5, 284–293). Methods and equipment used by Vauxhall Motors Ltd., Luton, for spot-welding passenger-vehicle doors, under-body assemblies and seat, sill-panel, and luggage-trunk lid assemblies are described. The machines used are manufactured by The British Clearing (Rockwell Machine Tool Co., Ltd.) and comprise four 4-pillar machines and one open face machine, both are of the upstroke design with maximum working pressure of 30 tons.—M. A. K.

The Bend Test. N. Ludwig. (*Schweissen u. Schneiden*, 1955, **7**, Sept., 387–391). The German Specifications DIN 50121, and DIN 50127 for weld bend tests are discussed. It is shown that only the bending angle will be useful as a criterion for weld ductility. A new bend testing machine is described developed by A. Hahn in which the position of the centre of the weld seam is being adjusted during bending by means of setscrews. The notched bend test according to DIN 50127 gave satisfactory results.—U. E.

The Determination of Weldability of Light Gauge Flat Steel Sheet. F. Eisenkolb. (*Schweissen u. Schneiden*, 1955, **7**, Sept., 404–407). A review is given of different testing methods for determining the weldability of light gauge flat steel sheet. The tendency to weld cracking is briefly discussed. (17 references).—U. E.

Longitudinal Induction Welding of Cold Formed Tubes. A. Fischer. (*Soudage Techn. Connexes*, 1955, **9**, Sept.-Oct., 229–235). Brief details are given of the method and the general and electrical plant required. Discussion.—T. E. D.

Submerged Arc Welding of Heavy Gauge Metals. L. Dubois. (*Soudage Techn. Connexes*, 1955, **9**, Sept.-Oct., 259–269). The applications of automatic submerged arc welding are given, with particular reference to the manufacture of high-pressure boiler plant components. The method is described and discussed.—T. E. D.

The Iron–Oxygen Combustion Process. A Study related to Oxygen Cutting. A. A. Wells. (*Brit. Welding J.*, 1955, **2**, Sept., 392–400). Measurements of the combustion rate of iron in oxygen are compared with calculations that determine the rate of diffusion of oxygen to the combustion face through a stagnant boundary layer of gaseous impurities. The thickness of this boundary layer is determined from a heat flow analogue. With certain exceptions it is concluded that the combustion rates for commercially pure reacting materials are mainly controlled by this diffusion mechanism.—U. E.

Some Investigations of the Causes of Halo Formation. K. Winterton. (*Brit. Welding J.*, 1955, **2**, Sept., 385–392). Tensile tests have been carried out on specimens of weld metal made with various electrodes in an attempt to relate

halo formation to hydrogen content, non-metallic inclusions, and straining conditions. It was found that appreciable strain together with the presence of hydrogen appear to be necessary and haloes may be observed only in fractured specimens and may not occur in any normal structure.—U. E.

Some Applications of Welding in the Development of Atomic Energy. L. Rotherham. (*Brit. Welding J.*, 1955, **2**, Sept., 377–383).

Effect of Preheating on Residual Stresses in Mild Steel Welds. L. E. Benson and S. J. Watson. (*Brit. Welding J.*, 1955, **2**, Sept., 372–376). Mean axial contraction stresses have been measured in preheated single run and multi-run test welds in mild steel. Preheating even at 400° C produced a reduction in residual stress of only about 50%, so that preheating cannot be regarded as a substitute for post-weld treatment at 600–650° C, which is known to produce substantially complete stress relief. No direct relationship appears to exist between residual stress and the 0·5% proof stress at the preheat temperature.—U. E.

Ways of Improving the Mechanical Properties of Metal Melted in Gas Welding. A. N. Shashkov and S. S. Vaksman. (*Avtog. Delo*, 1953, (3), 5–11). [In Russian]. In the investigation described the properties of deposited metal in the gas-welding of low-carbon steel were related to the type of filler rod used and the supplementary treatment to which the joint had been subjected.—S. K.

Control of Automatic Flame-Cutting Machines. A. G. Semenov. (*Avtog. Delo*, 1953, (3), 26–27). [In Russian]. The causes of crooked cutting by automatic flame-cutting machines are briefly considered and a simple procedure for avoiding this is described.—S. K.

Strength of the Weld Metal in the Gas Welding of Low-Carbon Steel. K. K. Khrenov and M. M. Bort. (*Avtog. Delo*, 1953, (6), 1–5). [In Russian]. The strength of gas welded joints in low-carbon steel which can be expected is considered and some improved methods for producing such joints are discussed.—S. K.

Impact Strength of O.H. and Bessemer Steel Welded Joints on Rolling Stock. S. V. Vershinskiĭ. (*Avtog. Delo.*, 1953, (6), 5–10). [In Russian]. The results of repeated impact tests on welded rolling stock frames of Bessemer and O.H. steel at air-temperatures down to — 18° C are presented and discussed. Using calculated impact data for rolling stock in service it is shown that the Bessemer steel used has only a small reserve of impact strength to withstand these.—S. K.

Manufacture in South Africa of Electrically and Fire Welded Chain. I. F. Wentzel. (*Engineer Foundryman*, 1955, **20**, May, 54–59, 63–64). The history of chain-making is briefly presented and South African practice in the manufacture of mild and high tensile steel chains using electric butt-welding machines is described. Fire welding is mentioned.—A. D. H.

Argonarc Welding. J. S. Owen. (*Engineer Foundryman*, 1955, **19**, Apr., 46–54, 67). The process of arc welding under an argon blanket is described in relation to older methods. Although mainly used for aluminium sheets, its application to the joining of stainless steel is described.—A. D. H.

LUBRICATION

The Contact Resistance and Mechanical Properties of Surface Films on Metals. R. W. Wilson. (*Proc. Phys. Soc.*, **B**, 1955, **68**, Sept. 1, 625–641). The nature of contact between sliding metal surfaces was investigated by measuring electrical contact resistance and the friction coeff., over a wide range of conditions, down to extremely light loads. Data were obtained, *inter alia*, for iron and for lead on steel. Changes occurring in the transition from oxide-on-oxide to metal-on-metal sliding were elucidated. The influences of the Beilby layer, the condition of the metal (annealed, electropolished or worked surface), and lubrication were also examined. Contact and sliding between metals can be explained by a single general pattern, which embraces the behaviour of oxide, Beilby, and lubricant surface films. (21 references).—K. E. J.

An Investigation of Heavy Duty Lubricating Oils by Electron Microscopy. F. T. Barwell, L. Grunberg, and D. Scott. (*Inst. Mech. Eng., Advance Copy*, 1955, Mar. 3). Details and micrographs are presented of electron microscope studies of a number of unused and used heavy duty (H.D.) oils, and also plain oils with and without additives. The suggestion that H.D. oils are colloidal suspensions is refuted. Two types of particle were however found in used H.D. oils and plain oils, one of the order of 0·05 micron, the other much larger (up to several microns in diameter). It is concluded that the electron microscope is unlikely to provide a very useful means for the inspection of unused H.D. oils. (4 references).—P. M. C.

Centralised Lubrication on Overhead Cranes Pays Dividends. N. Errington. (*Sci. Lubrication*, 1955, **7**, Sept., 22–24). Since the introduction of a continuous working week, at Consett Iron Co., Ltd., fully-automatic lubrication equipment was installed on an overhead crane in the melting-shop casting bay, to reduce off-time for maintenance. The bearings are of the phosphor-bronze split-bush type. Very substantial economies (details given) have resulted, in lubricant usage, maintenance man-hours, and bearing replacements, and automatic equipment is being fitted to all cranes in the department, and others.—K. E. J.

Method of Measuring Film Thickness of Solid Lubricants. H. M. McCullough and I. Sheinhartz. (*Trans. Amer. Inst. Min. Met. Eng.*, 1955, **203**; *J. Met.*, 1955, **7**, July, 822–823). The authors indicate that the superficial Rockwell hardness tester can be used to measure the thickness of sprayed graphite and similar lubricant coatings, to an accuracy of $\pm$ 0·00002 in. with a minimum film thickness of 0·0001 in.—G. F.

MACHINING AND MACHINABILITY

Recent Progress in Metal Cutting. F. Barbas. (*Usine Nouvelle*, 1955, **11**, Nov. 24, 27–31; Dec. 1, 35–37). The requirements of an aqueous cutting fluid are given and discussed. Some experimental work is reported, and suggestions are made on choice of fluid, means of moistening the cutting tool, tool-sharpening, and thermal treatment of the tool.—T. E. D.

Temperature Distribution at the Tool-Chip Interface in Metal Cutting. B. T. Chao and K. J. Trigger. (*Trans. Amer. Soc. Mec. Eng.*, 1955, **77**, Oct., 1107–1121). A rapid iterative method is prescribed for computing the distribution of temperature at the tool-chip interface.—D. H.

Predicting the Angle of Chip Flow for Single-Point Cutting Tools. L. V. Colwell. (*Trans. Amer. Soc. Mech. Eng.*, 1954, **76**, 199–204).

Friction Process on Cutting Tool and Cutting Mechanism. T. Sata and M. Mizuno. (*J. Sci. Res. Inst.*, 1955, **49**, June, 163–174). Metal cutting is discussed in terms of shearing friction. In dry cutting, chips are in perfect contact with the tool and are in a yielding state. New expressions for the shear angle and angle of friction on the tool agree well with reported data. The thermal effect in high-speed cutting is discussed.

Methods and Instruments for Measuring Machined Surfaces. C. K. Nissen. (*Tek. Ukeblad.*, 1955, **102**, May 26, 435–439). [In Norwegian]. After describing the use of the comparator microscope and standard surface gauges, the author outlines the applications of quantitative two-dimensional methods for checking surface smoothness, such as the oblique cut, the Schmaltz light cut and the interference microscope.—G. G. K.

Recent Developments in the Theory and Design of Electric Spark Machine Tools. E. M. Williams, J. B. Woodford, Jr. and R. E. Smith. (*Trans. Amer. Inst. Elect. Eng.*, 1954, **73**, Part II, 83–88). The theory underlying electric spark machining is discussed, and a number of recent developments in machine design are described.—L. D. H.

Review of Surface Finish Literature. J. W. Sawyer. (*Machine Design*, 1955, **27**, May, 155, 333, 335, 338, 340, 342, 344, 347, 350, 352, 354). The review covers 1952 and 1953 and includes 119 references, abstracts, and an index listing subjects mentioned in the review papers.—M. A. K.

A Review of the Developments in the Measurement and Specification of Surface Finish. J. Halling. (*Trans. Liverpool Eng. Soc.*, 1953, **74**, 65–82). The influence of the surface state of the material on the behaviour of that material in service is investigated. Methods of specifying and measuring surface finish are discussed.—U. E.

Some Methods of Economic Belt Polishing. G. Pahlitzsch and H. Windisch. (*Metall*, 1955, **9**, June, 496–499). Investigations of the relative merits of different surfaces and materials of construction of contact wheels are reported; a cost comparison was included in the investigation.—J. G. W.

CLEANING AND PICKLING

Degreasing of Metal Components with Trichlorethylene. A. G. Gardener. (*Metal Finishing J.*, 1955, **1**, Aug., 349–356). Solvent and vapour processes of degreasing using trichlorethylene are described. Plant design, operation, and contamination of the solvent are considered.—A. D. H.

Degreasing Systems and their Choice. D. J. Fishlock. (*Product Finishing*, 1955, **8**, Aug., 48–50; Sept., 50–55). Physical and chemical methods of removing oil and grease from metals are discussed and examples of plant are given together with methods of control.—A. D. H.

An Example of Work Simplification in Fettling Operations. F. C. Pearce. (*Brit. C.I. Res. Assoc. J. Res. Dev.*, 1955, **6**, Aug., 16–19). Some practical attempts and achievements to simplify fettling operations during the production of piston casting are described.—B. G. B.

Complex Transmission Castings Cleaned, Descaled Electrolytically. J. Birnbaum. (*Iron Age*, 1955, **176**, Sept. 22, 116–118). An automatic installation for cleaning complex grey iron transmission castings is described. It incorporates the "Kolene" process which uses an electrically activated, catalysed, molten oxidation or reduction salt bath.—D. L. C. P.

Continuous Pickling of Stainless Steel. F. F. Jaray. (*Metal Finishing*, 1955, **53**, Mar., 68–72). The construction of two pickling lines for the continuous pickling installed by Firth-Vickers Ltd. at Sheffield are described. The hot rolled material is first descaled in a sodium hydride bath and then pickled in 10% HNO_3–3% HF. The first tank of the cold line uses electrolytic pickling in 15% HNO_3, the second uses 12% HNO_3–3% HF. Acid storage, neutralization, and fume extraction are also discussed.—A. D. H.

A New Method of Descaling Steel. (*Usine Nouvelle*, 1955, **11**, Aug. 18, 39). In the presence of an electrolyte the iron, which forms the anode, dissolves, and hydrogen is released at the Fe_3O_4, causing it to be lifted from the iron. In the Fradecal process, a paste containing a strong electrolyte is spread on the surface to be descaled. The paste also contains a strong oxidizing agent such as dichromate or permanganate, which removes hydrogen rapidly from the Fe_3O_4 cathode and prevents polarization, thus allowing descaling to proceed.

Present State of Surface Finishing. H. Finkelnburg. (*Metall*, 1955, **9**, June, 466–471). This is a survey of mechanical finishing processes with only a brief reference to new non-mechanical methods. The processes described comprise lapping, honing, superfinishing, surface rolling, and shot-peening.—J. G. W.

Degreasing of Metal Parts by Volvent Vapours. A. Arnold. (*Metall*, 1955, **9**, June, 483–486). Following an historical survey referring to various German patents, vapour-degreasing methods are described together with their uses.—J. G. W.

Save on Snagging. J. A. Mueller. (*Steel*, 1955, **136**, June 20, 110–112). The results of an investigation into abrasive-wheel grinding in which the effects of wheel speed, pressure, and wheel structure on production rate, power consumption, and wheel performance are given. It is concluded that constant wheel-surface speed is desirable.—D. L. C. P.

Developments in Preparatory Treatments. (*Corrosion Prevention and Control*, 1955, **2**, Feb., 45–47, 51; Apr., 29–32; June, 37–39; July, 41–43). A description is given of barrel finishing and shot and sand blasting in terms of their applications, operating procedures, and equipment required. This is followed by a consideration of cleaning and pickling with particular reference to oxide film effects, pickling studies and ultrasonic cleaning. Finally, specific chemical treatments are given for various metals and alloys. (30 references).—L. E. W.

Cleaning With Ultrasonics. F. W. Hightower. (*Metal Progress*, 1955, **68**, July, 99–104). The advantages and practical use of ultrasonic methods of cleaning are discussed. The method is of particular use where the surfaces to be cleaned are not readily accessible or when they must be scrupulously clean as for plating or adhesive bonding. Examples of the commercial use of this technique are described.—B. G. B.

On the Shot for Peening. III. M. Uchiyama and K. Kamishohara. (*Tetsu to Hagane*, 1955, **41**, Oct., 1093–1097). [In Japanese]. Studies showed that: (*a*) the size of the surface indentation increases with shot speed and dia.; (*b*) peening intensity increases with shot size, speed, and hardness; (*c*) surface roughness increases as in (*b*), although initial surface roughness may be reduced by peening; (*d*) soft, heat-treated steel or iron shot produces sufficient peening intensity, with surface roughness; and (*e*) broken shot reduces peening intensity without affecting roughness.—K. E. J.

Blast Cleaning. A. Oreffice. (*Fonderia Ital.*, 1955, **4**, July, 332–334). [In Italian]. The author describes the blast cleaning process for castings, the use of both ferrous and non-ferrous metal particle abrasives and the equipment to be used.

Effect of Adsorbed Acid Pickling Inhibitors on Activity of Steel. A. Adachi. (*Techn. Rep. Osaka Univ.*, 1955, **5**, Mar., 153–160). The surface activities of sheet iron when pickled in 1N-sulphuric acid with and without various inhibitors, were investigated electrochemically.—J. G. W.

Mechanical Descaling of Wire Rod by Bending. C. Eisenhuth. (*Stahl u. Eisen*, 1955, **75**, Aug. 25, 1092–1099). The effect of descaling rod by passing it over two rolls with axes at right-angles, as compared with pickling, has been investigated. It was found that mechanical descaling caused smaller losses in weight than did pickling, because the latter dissolved steel from areas from which scale had been removed during the pickling process. In general, the surface of the mechanically descaled rod was better, though since the scale breaker forms part of the drawing arrangement, it is not possible to apply a lubricant carrier; the resultant wire is often not so good as that produced from pickled, sull-coated, and limed rod. The mechanical properties of wires from mechanically descaled rod are generally similar to those of wire from pickled rod and the wear on the drawing dies is of the same order.—J. P.

Finishing of Stainless Steels. (*Acciaio Inossid.*, 1954, **21**, Nov.-Dec., 163–167). [In Italian]. A brief review is given of the precautions which must be taken and the techniques which are adopted in preparing highly-polished stainless steels.—M. D. J. B.

On the Reduction of Ferric Sulphate with Sulphur Dioxide. M. E. Pozin, I. P. Mukhlenov, and L. S. Vasilesku. (*Zhur. Priklad. Khim.*, 1955, **28**, (6), 573–578). [In Russian]. The influence of temperature, concentration of sulphur dioxide and oxygen in a gas mixture on the velocity of reduction of ferric sulphate into ferrous sulphate as applied to the production of sulphuric acid using iron as a catalyst was studied. The experimental results confirmed the possibility of a simultaneous utilization of waste gases and spent pickle liquors for their regeneration or for the production of sulphuric acid.—V. G.

Oxidation of Ferrous Sulphate in Acid Aqueous Solutions with Oxygen from Air. I. N. Kuz'minykh and M. D. Babushkina. (*Zhur. Priklad. Khim.*, 1955, **28**, (6), 565–572). [In Russian]. The velocity of heterogeneous oxidation process of ferrous sulphate in aqueous acid solutions of various acidity by bubbling air was studied. The influence of concentration of free sulphuric acid, $Fe^{\cdots}$ ions and oxygen, temperature of the reaction, and the presence of copper on the velocity of oxidation was established.—V. G.

A Modern Works for the Surface Treatment of Nickel Alloys and Stainless Steels. M. Perret. (*Rev. Nickel*, 1955, **21**, Jan.-Mar., 1–11). The high resistance to corrosion by mineral acids of nickel alloys and stainless and high-temperature steels, makes their surface treatment difficult, and particularly active baths must be used for descaling and preparation of surfaces before cold deformation. The materials, methods, and plant of the Rueil works of Les Tréfileries et Laminoirs de Précision Gilby-Fodor for treatment of nickel alloys and stainless steels in the form of wire, tape, tubes, and bars are described.—T. E. D.

Alkaline Solutions: What to Use for Effective Cleaning. J. B. Mohler. (*Iron Age*, 1955, **176**, July 28, 59–62). The basic compositions of alkaline cleaning solutions are given, and methods of use and applications are considered.—D. L. C. P.

PROTECTIVE COATINGS

Electroplating Equipment: Layout — Installation — Maintenance. R. Allen. (*Metal Ind.*, 1955, **86**, Jan. 28, 67–70; Feb. 11, 107–110; Feb. 25, 147–150). Part 1 deals at length with the design and construction of buildings suitable for the installation of electroplating equipment, and the guiding principles to be considered in the layout of the plant. Part 2 deals with types of tank lining for different solutions, and the relative merits of and equipment required for steam, gas, and electric heating of plating and pickle solutions. The generation and supply of electroplating current is also discussed. Part 3 deals with fume extraction equipment, filtration plants and the use of plating jigs.—P. M. C.

Science for Electroplaters. VII. Formulas. L. Serota. (*Metal Finishing*, 1955, **53**, Oct., 62–64). An elementary account of valency and chemical nomenclature is given.—A. D. H.

New Plating Process Comes to Canada. L. W. Piddington. (*Canad. Metals*, 1955, **18**, July, 24–26). A short account of the Dalic process for the deposition of metal coatings on worn parts is given.—B. G. B.

The Alloy Growth Rate of 0·25 Pound Electrolytic Tin Plate in the Temperature Range, 380–440° F. W. N. Lambert. (*Corrosion*, 1955, **11**, Oct., 56–60). Quarter pound electrolytic tin plate was immersed from five seconds to thirty minutes in oil baths at 380, 400, 420, and 440° F. The growth of the tin–iron alloy for each temperature and initial alloy layer was plotted and the rate of growth of the alloy layer was determined. In order to have the least alloy after baking, the baking temperature should be as low as possible. A decrease of 20° F allows double the baking time for the same residual free tin.—J. F. S.

Spectrographic Method for Determining the Thickness of Electrolytic Deposits. V. P. Borzov and E. V. Il'ina. (*Zavodskaya Laboratoriya*, 1955, **21**, (3), 327–331). [In Russian]. An account is given of the determination of the thickness of various single and multiple electrolytic deposits on steel and some other alloys. The basis of the method is the change with time of the intensity of the lines of the coating elements in an arc burning between the test-piece and another metal electrode. The preparation of standard specimens and the respective procedures for single- and multiple deposits are described, the probable errors of the results being tabulated. Some calibration curves are presented.—S. K.

The Measurement of Current Density in an Acid Copper Plating Solution. E. J. Wilhelm and R. F. Kayser. (*Plating*, 1955, **42**, Apr., 406–412).

The Influence of the Physical Metallurgy and Mechanical Processing of the Basic Metal on Electroplating. I. Critical Review of the Literature. II. Correlated Abstracts. A. E. R. Westman and F. A. Mohrnheim. (*Plating*, 1955, **42**, Feb., 154–158; Mar., 281–286; Apr., 417–421). A comprehensive review is made of the influence of steel manufacture, forming, grinding, polishing, buffing, cleaning, and plating on the electrodeposition of nickel or nickel–chromium on steel. It is concluded that the micro-geometry of the steel surface is probably an important factor in accelerating breakdown of coatings and that more careful experiments having a metallurgical approach are required. (198 references).—A. D. H.

New Instrument Controls Rinse Tank Flow Automatically. J. B. Mohler. (*Iron Age*, 1955, **176**, Aug. 18, 82–83). The "Solubridge" is an automatic controller for rinse tanks which can reduce water consumption by at least a half. It measures, by means of rinse water conductivity, the concentration of all chemicals present and regulates the water flow accordingly.

Inhibited Acids in Plating Cycles. J. W. Carroll. (*Metal Finishing*, 1955, **53**, Mar., 60–63).

Coatings: Good Structural Design Aids Battle Against Corrosion. C. G. Munger. (*Iron Age*, 1955, **176**, July 14, 108–111). Trouble spots in structures which must be protected from corrosion are pointed out; means of minimizing the incidence of these areas and of best protecting them are considered.

Get Better Adhesion by Checking Plating Solutions Spectrographically. A. M. Howard. (*Iron Age*, 1955, **176**, July 7, 98–101). A description is given of how a plant overcame poor adhesion of electroplating, by employing spectrographic analysis of solutions to detect impurities.—D. L. C. P.

Opportunity Knocks for Gas Plating. (*Steel*, 1955, **137**, July 11, 106–108). Vapour deposition processes and applications are described and properties of the coatings given.

Treatment of Electroplating Wastes. A. E. J. Pettet. (*Product Finishing*, 1955, **8**, July, 54–60; Aug., 57–63, 102). The problem of effluent disposal is discussed generally. Methods of removing chromic acid, cyanide, and metals are described in detail.—A. D. H.

Electroless Nickel Plating and its Applications. Bosdorf. (*Electroplating Metal Finishing*, 1955, **8**, Dec., 415–417, 428). The effect of variations in bath composition of a hypophosphite bath for nickel plating has been determined. The properties of the coating are given.—A. D. H.

Nickel Plating. F. Dyngvold. (*Tek. Ukeblad*, 1955, **102**, Apr. 14, 303–307). [In Norwegian]. The author discusses suitable applications for nickel plating, historical developments and the theory of the Watts bath; also the mechanism of bright nickel plating and the reactions occurring in chemical nickel plating by the Kanigen process.—G. G. K.

A New Look at Electroless Nickel Plating. J. L. Chinn. (*Mat. Methods*, 1955, **41**, May, 104–106). In this process a uniformly thick plate is deposited wherever the metal is in contact with the solution, an advantage where intricately shaped parts are being dealt with. The plate is deposited by reducing a nickel salt by sodium hypophosphite, and consists of 93 to 97% Ni, the remainder being phosphorus. The plate is quite hard and wear resistant, and for many applications is superior to electroplated nickel.—P. M. C.

Rapid Method for Testing and Correcting the Acidity of Nickel Electrolytes. T. I. Moldaver. (*Zavodskaya Laboratoriya*, 1955, **21**, (3), 305). [In Russian]. A brief account is given of a simple and rapid method for finding the quantity of acid to be added to nickel-plating baths to maintain correct acidity.—S. K.

New Continuous Galvanizing Line Produces Light Coatings. N. E. Cook. (*Iron Age*, 1955, **176**, Sept. 29, 68–70). A new continuous strip galvanizing line at Wheeling Steel Corp. is described. Capacity is 40–50 tons per hour of 10–24 gauge steel strip up to 48 inches wide. The zinc has an aluminium addition which prevents the formation of brittle iron–zinc alloy layers.—D. L. C. P.

Some Notes on the Effect of the Presence of Iron Salts in Hot-Dip Galvanizing. H. Bablik, F. Götzl, and E. Nell. (*Metal Finishing J.*, 1955, **1**, Aug., 347–348). The deleterious effect of iron salts in galvanizing baths containing aluminium are emphasized. Crystals of $FeAl_3$ are formed in the vicinity of the treated sheet and the beneficial effect of the added aluminium is lost.—A. D. H.

The Roughness of Various Pre-Treated Surfaces and their Importance for Hot-Dip Galvanizing. H. Bablik, F. Götzl, and E. Nell. (*Metalloberfläche*, 1955, **9**, May, A69–A73). The degree of roughness of a metal surface to be galvanized by the hot dip process is of interest, as too smooth a surface is unsuitable. With this in mind, a series of trials was carried out on the effect of pickling on sheet surface roughness, this property being measured by a Forster-Leitz apparatus. The sheet was rolled through wire rolls, then pickled by various methods or sand blasted. The results are discussed, and an expression is derived giving the roughness in terms of the ratio between the surface tensions of the steel and its zinc coating.—L. D. H.

Structure and Determination of the Thickness of Zinc Coatings. W. Katz. (*Stahl u. Eisen*, 1955, **75**, Aug. 25, 1101–1106). An anodic stripping process is described in which the thickness of the various alloy layers in a zinc coating is measured by the amount of electricity passed to remove them. The removal of the layers is indicated by a change in the potential of the dissolving zinc coating. The results obtained agree within $\pm$ 2% with those by the chemical stripping and weighing method. Equipment has been developed for performing the measurements automatically.—J. P.

How the Small Electroplater Can Treat Cyanide Plating Waste Solutions with Hypochlorites. B. F. Dodge and W. Zabban. (*Plating*, 1955, **42**, Jan., 71–75). A description is given of the detoxification of cyanide-containing effluent with hypochlorite. The method is simple and suitable for solutions containing < 5000 p.p.m. of cyanide. A method for determination of < 1 p.p.m. cyanide is given.—A. D. H.

Depreciation and Maintenance of Metal Finishing Plant. IV. Interest on Capital as a Factor in Electroplating Costs. S. H. Withey. (*Electroplating*, 1955, **8**, Jan., 11–12). An example of the importance of allowing for interest on capital expenditure is given and applied to a metal spraying and enamelling firm.—A. D. H.

An Experimental Investigation of the Metal Spraying Process. II. A. Matting and K. Becker. (*Electroplating*, 1955, **8**, Apr., 143–145). The characteristics of the spray of metal from a commercial spray gun were investigated using a high-frequency micro-camera and a micropyrometer. The influence of variations in the acetylene : oxygen ratio on the disintegration of aluminium and steel wire during spraying was demonstrated.—A. D. H.

Electrochemical Investigation of Passive Iron. L. V. Vanyukova and B. N. Kabanov. (*Zhur. Fiz. Khim.*, 1954, 28, (6), 1025–1035). [In Russian]. The following main conclusions are drawn from an electrochemical investigation of a passive iron electrode in alkaline solutions during anodic polarization: (1) the anodic oxidation process consists of the relatively fast electrochemical absorption of oxygen and the slow deep oxidation of the iron; (2) the capacity of the double layer of electrodes of iron oxidized by heating in air is about a quarter of that of the oxide-free metal; (3) absorbed chloride ions slow down both oxygen-absorption and deep-oxidation processes, the absorption of chloride ions being very slow.

Contribution to the Study of Electrolysis in Very Concentrated Solutions. Examples of Electrolytic Polishing. P. Brouillet.

(*Métaux–Corrosion–Indust.*, 1955, **30**, Apr., 141–153; May, 192–219; June, 243–257). The results of a detailed study of electrolysis in a wide range of concentrated solutions are reported. (73 references).—B. G. B.

Complex Ions in Chromium Plating Solutions. G. Gabrielson. (*Metal Finishing*, 1955, **53**, May, 56–58). It is shown that cation exchange resins form complexes with chromate ions and the consequences of complex formation on bath purification and the mechanism of deposition are discussed.—A. D. H.

Standardization of Chromium Bath Tests on a Bent Cathode in the Hull Cell. R. H. Rousselot. (*Metal Finishing*, 1955, **53**, May, 50–53, 55; June, 99–102). The development of a method of measuring covering power using a bent cathode in a Hull cell is described. The cell is used to study the effect of bath and metal variables on covering power during the deposition of chromium.—A. D. H.

Porous Chromium Coatings. R. Josse and N. Manson. (*Mem. Soc. Ing. Civils France*, 1955, **108**, May-June, 235–257). A comprehensive review of the use of these coatings for the reduction of wear on moving parts, primarily engine cylinders, is presented. The surface structure, technique of forming the coating, and the effect of such coatings on the mechanical properties of specimens are described. (34 references).—B. G. B.

Hard Chromium Troubles. C. F. Corfe. (*Product Finishing*, 1955, **8**, June, 65–70). The reasons for faults and the methods of curing them in hard chromium plating are given in table form.—A. D. H.

Electrodeposition of Nickel from Fluoborate Solutions. C. B. F. Young and W. Strobach. (*Metal Finishing*, 1955, **53**, July, 44–50; Aug., 53–58; Sept., 79–85). The characteristics of the deposition of nickel from fluoborate solutions have been investigated. Bath composition, current density, throwing power, and properties of the deposits were investigated.—A. D. H.

Tin Fluoborate Plating. J. B. Mohler. (*Metal Finishing*, 1955, **53**, Apr., 59–61). The control of a tin fluoborate bath using a plating range test for thick and thin deposits is described.—A. D. H.

Kinetics of the Electrolytic Deposition of Nickel. S. V. Gorbachev and Yu. N. Yurkevich. (*Zhur. Fiz. Khim.*, 1954, **28**, (6), 1120–1128). [In Russian]. In the investigation described the effects of temperature, concentration, and current density on the electrolysis of nickel solutions and the nature of the deposit were studied.—S. K.

Electrodeposition of Heavy Nickel. D. J. Fishlock. (*Product Finishing*, 1955, **8**, June, 54–62, 110; July, 66–74). Methods and plant for the deposition of heavy nickel for wear and corrosion resistance are described. Methods of bath control and for testing the quality of the deposit are given.—A. D. H.

A Simple Coulometer Method for Tin Coating Determination. J. Monvoisin and M. LeBlanc. (*Tin and its Uses*, 1955, (33), Oct., 3–5). Apparatus is described for the rapid determination of tin coating thickness by measuring the quantity of current required for its anodic dissolution.—A. D. H.

Tin Alloy Coatings as Alternatives to Nickel/Chromium. S. C. Britton. (*Tin and its Uses*, 1955, (33), Oct., 10–12). The results of atmospheric exposure tests show that the substitution of part of the nickel layer in nickel/chromium coatings by a layer of tin–bronze reduced porosity and that tin–nickel coatings are as resistant as chromium.—A. D. H.

Electrolytic Coatings of Tin–Zinc Alloys. T. W. Cuthbertson. (*Metalloberfläche*, 1955, **9**, Aug., B113–B116). [In German]. This article discusses the chemical reactions occurring in electrolytic plating by means of a Zn–Sn cyanide bath. The composition of the bath and anodes, working conditions, and applicability of the process are dealt with. The properties of the coating are described.—L. D. H.

Hot-Tinning Cast Iron. C. J. Thwaites. (*Tin and its Uses*, 1955, (33), Oct., 5–6).

Diffusion Coatings with Metallic Halides. I. Jenkins. (*Product Finishing*, 1955, **8**, Sept., 61–67; Oct., 61–66, 108). The theory and practice of processes involving a chemical reaction between a solid and a gas are discussed. Halide processes are considered in detail and the physical properties and applications of diffusion coatings are given.—A. D. H.

Hot Dip Aluminium Coating Iron and Steel Wire. B. S. Westerman. (*Products Finishing*, 1955, **19**, Sept., 62–69). A process developed by the American Chain and Cable Co. for the aluminium coating of wire is described. The wire is pickled in HCl, washed, and passed through a hot aqueous solution of zirconium and titanium fluorides before dipping in molten aluminium. The characteristics of the process and properties of the coating are described.—A. D. H.

Electrodeposition of Titanium on Base Metals. M. E. Sibert and M. A. Steinberg. (*J. Electrochem. Soc.*, 1955, **102**, Nov., 641–647). A method is described for the electrodeposition of titanium from potassium titanium fluoride dissolved in molten alkali or alkaline earth halides. Adherent coatings up to 0·005 in. in thickness may be produced on steel or other base metals.—A. D. H.

The Electrodeposition of Aluminium. R. J. Heritage. (*Bull. Inst. Met. Finishing*, 1955, **5**, Summer, 106–118).

The Cladding of Steel and Reinforced Concrete with Thin Corrosion-Resistant Sheets. P. Voigt. (*Werkstoffe Korrosion*, 1955, **6**, July, 337–343). This is a good and interesting account of modern techniques for cladding ordinary steel with thin sheets of rust-resisting steel so as to produce corrosion-resistant vessels, such as plant for the chemical industry. The process can be adapted for use on reinforced concrete, if a suitable steel grid is embedded in the surface of this, to which the cladding sheet can be welded.—J. C. H.

Nylon-Coated Metal Parts for Wear Resistance. L. L. Stott. (*Mat. Methods*, 1955, **41**, June, 92–94). A new coating process developed by the Polymer Corp., Reading, Pa., U.S.A., makes it possible to combine the good frictional and anti-wear characteristics of nylon with the better dimensional stability and strength of metals. Adherent coatings ranging in thickness from 0·002 to 0·030 in. have been applied to many types of steel. Applications include the coating of cams, rollers, bushings, guides, gears, etc.—P. M. C.

Preliminary Surface Treatment and Lacquering of Sheet in the Industrial Treatment of Sheet Products. H. Anders. (*Metalloberfläche*, 1955, **9**, Aug., B116–B118). A general outline is given of modern methods of preparing and lacquering metal sheet.—L. D. H.

Amorphous Phosphate Coatings from the Metabond Bath. J. A. Henricks. (*Products Finishing*, 1955, **19**, July, 74–76). The characteristics and uses of a proprietary non-sludge forming zinc phosphating bath ('Metabond') are described.

Inside of Pipe and Tubing Coated by Horizontal Processing Method. (*Indust. Heating*, 1955, **22**, Aug., 1643–1648). Spraying equipment and curing ovens for applying a coating of corrosion resistant Epon-resin to the bore of tubes for rock drills are described.—A. D. H.

Metal Spraying. A. E. Williams. (*Steam Eng.*, 1955, **24**, Apr., 234–237; May, 284–286; June, 317–319; July, 362–364; Aug., 386–388). The wire process and the powder process are each described briefly, and surface preparation before spraying is mentioned. Metal spraying with zinc, aluminium, cadmium, tin, lead, or stainless steel, as a means of protecting against corrosion, is described. High temperature protection, particularly by means of the aluminizing process, is discussed. Reclamation of worn parts is another use for metal spraying. The properties of sprayed metal surfaces are examined.

Metal Spraying for High Temperature Resistance. S. M. Holgate. (*Electroplating*, 1955, **8**, June, 219, 226). American and British metal spraying practices are compared.—A. D. H.

Electric Furnaces for Vitreous Enamelling. (*Wild Barfield Heat Treatment J.*, 1955, **5**, Sept., 11–15). The advantages and the use of electrically heated furnaces in the vitreous enamelling industry are described.—D. H.

Finishing Products at Electrolux Ltd. (*Indust. Finishing*, 1955, **9**, Oct., 146–152). Plant for vitreous enamelling, electrostatic paint spraying, etc. are described.—A. D. H.

Estimation of the Thermal Expansion of Enamels and Enamel Frits by the Stress-Optical Test. H. J. van Buren. (*Amer. Ceram. Soc. Bull.*, 1955, **34**, Aug., 261–263). In the method described, expansion of a porcelain enamel glass is estimated by optically determining the stress in a standard glass which has been fused to it. The method is proposed in particular for the control of batches of enamel frit.—D. L. C. P.

Effect of Smelting Treatment on the Abrasion Resistance of Commercial Dry-Process Enamel. W. C. Spangenberg. (*Amer. Ceram. Soc. Bull.*, 1955, **34**, Aug., 245–247). Evaluation of several enamels smelted under commercial conditions confirmed that the resistance to abrasion of dry-process acid-resisting enamel was improved with extended smelting treatment and other modifications, without detriment to the acid resistance and opacity of the enamels.—D. L. C. P.

Distribution of Crystals in Titania Enamels Fired Directly on Steel. E. D. Lynch and A. L. Friedberg. (*J. Amer. Ceram. Soc.*, 1955, **38**, Aug., 257–263). A new technique for studying

the crystalline material in fired enamel is described. It was found that the presence of FeO crystals at the interface was necessary for a good bond. The effect of certain processing treatments on FeO formation is discussed briefly.—D. L. C. P.

Lacquer, Synthetic Enamel Coatings and Stoving Finishes. A. A. B. Harvey. (*Indust. Finishing*, 1955, **9**, Sept., 84–88; Oct., 143–145). The principles governing the selection of paint coatings and their application are discussed with reference to the motor car trade.—A. D. H.

Steel Product Preparation and Finishing Operations. C. R. Syer. (*Indust. Finishing*, 1955, **9**, Aug., 44–55). The author describes the setting up and control of a plant for lining and painting steel drums in the Far East.—A. D. H.

POWDER METALLURGY

High Strength Steel Parts by New Powder Metallurgy Process. J. W. Young. (*Metal Progress*, 1955, **68**, July, 110–113). A brief account of the manufacture of small parts having high strengths by powder metallurgy is presented.—B. G. B.

New Infiltration Method and the Properties of Sintered Iron–Brass Compounds. E. Pelzel. (*Metall*, 1955, **9**, Sept., 783–790). The principles of various methods of infiltrating porous sinter compacts with metals are surveyed, followed by an account of an investigation of the method based on submerging the compact in liquid metal, with a range of brasses and three grades of sintered iron. The compounds thus prepared were tested mechanically, whence the effect of brass composition on the mechanical properties of the compound was ascertained.—J. G. W.

Magnetic Behaviour of Fe–Ni Compacts under Sintering Process. H. Kojima. (*Sci. Rep. Res. Inst. Tohôku Univ.*, A, 1955, **7**, June, 321–328). Densities and magnetic properties of Fe–Ni compacts were measured as a function of the sintering temperature and nickel content.—J. G. W.

Ferrous Sinter-Alloys Containing Boron. F. Benesovsky, W. Hotop, and F. Frehn. (*Planseeberichte*, 1955, **3**, Aug., 57–70). The influence of additions of ferro-boron on the properties of various sintered irons was studied, including stainless steels. An increase in density was noted when small additions of ferro-boron were made, thus increasing the tensile strength and elongation. Large amounts of ferro-boron cause brittleness. (16 references).—R. P.

Europe Goes Ahead in Iron-Powder Metallurgy. S. I. Hulthén. (*Metalworking Prod.*, 1955, **99**, Aug. 19, 1449–1454). In a paper presented at the meeting of the U.S. Metal Powder Association earlier this year, the author reported that emphasis is on quality in European powder metallurgical practice. In this abstract from his paper he reviews trends. A further instalment will deal with tooling.—M. A. K.

A Design Appraisal of Pre-alloyed Steel Powders. G. A. Roberts and A. H. Grobe. (*Machine Design*, 1955, **27**, July, 204–208). The characteristics of two types of pre-alloyed steel powders are discussed. One group is composed of the high-strength, low alloy steel powder where hardenability is an important factor and the other comprises the stainless steel powders where corrosion resistance is required.—M. A. K.

Concerning the Effect of Carbon Content on the Quality of Sintered Carbides of the W–C–Co Type. M. Petrdlík and V. Dufek. (*Hutnické Listy*, 1955, **10**, (9), 528–535). [In Czech]. Sinterability of the system WC–Co was studied as a function of its carbon content. During preliminary sintering in hydrogen the carbide is decarburized to 0·3–0·1% C, but is recarburized during the final stage of sintering, particularly if this is carried out in soot, and the carbon content has not been allowed to drop below 0·15%. Effects due to oxygen combined with cobalt were not observed. In the absence of a binder the sinterability of tungsten carbide is best when the amount of carbon present is approximately stoichiometric; the presence of W_2C results in appreciable deterioration of the sinterability. Tests on sintering WC containing 2·6% and 10% of cobalt showed that the best combination of hardness, density and strength in bending result from a carbon content which is, again, stoichiometric. An attempt is made to explain the nature of chemically and structurally differing phases which appear in platelet form in the carbide initially if W_2C is present.—P. F.

Characteristics of Copper-Infiltrated Porous Iron. J. E. Elliott. (*Metallurgia*, 1955, **52**, Nov., 226–234). The effect of iron solubility in the copper infiltrant on surface defects is considered and the performance of a copper–iron–manganese infiltrant is assessed. Structural changes in the skeleton during infiltration can be explained in terms of alloying effects. The basic principles of infiltration are described.

Porous Metal Sheet. J. B. Campbell. (*Mat. Methods*, 1955, **41**, Apr., 98–101). The production and properties of porous metal sheet, notably of stainless steels, are described. Controlled permeability plus resistance to heat and corrosion make these new materials useful for many special applications in the aircraft field, and as filters, aerators, and for transpiration cooling of combustion chambers.—P. M. C.

Stainless Steel Powder Parts. A. Adler, (*Mat. Methods*, 1955, **41**, Mar., 118–120). The methods of production, properties, and applications of parts made from pre-alloyed stainless steel powders are reviewed. The powders are produced by intergranular attack on the steels, which are subsequently broken down mechanically and screened. All types of stainless steels are available in powder form and their many applications include porous gaskets and filters, and a wide variety of small structural parts. Such parts have good wear and strength properties and high corrosion resistance.

New Trends in Powder Metallurgy. H. B. Michaelson. (*Mat. Methods*, 1955, **41**, Apr., 92–97). A general review is made of recently developed techniques, including the continuous rolling of strip directly from metal powder, the production of high hot-strength steel parts, the fabrication of sheet by flame spraying, the preparation of porous corrosion-resistant sheet, and the sintering of reactive metals such as zirconium from their hydrides. (11 references).—P. M. C.

Dewrance T.L.B. Hard-facing Equipment. (*Machinery*, 1955, **87**, Sept. 2, 563–564). For hard-facing engineering parts, the facing metal, in powder form, is fed to the nose-piece of an oxy-acetylene welding torch. Features of this attachment are that the need for a filler rod is obviated and deposits up to $\frac{1}{8}$ in. thick can be obtained at one pass. It has been developed for the deposition of a variety of Dewrance–Coates alloys and is also suitable for the application of other facing metals, i.e. Stellite, Colmonoy, brasses, bronzes, and copper.—M. A. K.

A New Method for Measuring Specific Surface Area of Porous Bodies and Powders. B. Deryagin, R. Fridlyand, and V. Krylova. (*Doklady Akad. Nauk SSSR*, 1948, **61**, (4), 653–656). [In Russian]. The method is based on the measurements of the resistance to flow of gas through a bed of the material investigated at low pressures. A description of the apparatus used is given.—V. G.

Behaviour of Powdered Metals During Pressing. S. Valente. (*Ing. Mecc.*, 1955, **4**, Aug. 27–31). [In Italian]. Results are given of research carried out to check the relation between pressure and consolidation proposed by Bal'shin. A new formula is given which agrees with experimental results obtained.—M. D. J. B.

Properties and Uses of Sintered Permanent Magnets. Z. Ministr. (*Hutnické Listy*, 1955, **10**, (7), 389–396). [In Czech]. Production methods and properties of sintered and cast Alni and Alnico magnets are discussed, and shapes of magnets amenable to powder metallurgical production are considered. A new method of joining sintered ring-shaped magnets to shafts by means of soft inserts is described. Details of properties of ferritic magnets, of magnets made from finest-grained powders without sintering, and of Bi–Mn type magnets are given.—P. F.

PROPERTIES AND TESTS

On the Mechanism of Cavitation Damage. M. S. Plesset and A. T. Ellis. (*Trans. Amer. Soc. Mech. Eng.*, 1955, **77**, Oct., 1055–1064). The effects of cavitation have been studied on a variety of hard and soft materials ranging from stellite to aluminium and including 18/8 stainless steel and a 1% CrMo steel. A new method for producing cavitation damage is described in which alternating pressures are generated in the water over the specimen by exciting a resonance in the "water cavity."—D. H.

Progress in the Field of Mechanical and Non-Destructive Testing in 1953 and 1954. W. Schatt. (*Technik*, 1955, **10**, Oct., 605–614). This is a brief summary of developments in plasticity theory, tensile testing technique, high temperature creep; compression, bend, torsion, hardness testing; brittleness, impact testing; fatigue and fatigue testing; the testing of welds, sheets (deep drawing capacity), of wear resistance, resilience, hardenability, machinability. The non-destructive

methods surveyed comprise X-ray, ultrasonics, magnetic powder, inductive and eddy-current. The bibliography contains 251 items.—J. G. W.

Fortiweld, A Low Creep Fabrication Steel. H. F. Tremlett. (*Metalworking Prod.*, 1955, **99**, Oct. 21, 1796–1798). Resistant to softening under welding conditions, this steel may be cold-worked and tempered to 40 tons per sq. in. tensile strength. Composition, physical properties, and methods of using this recently developed material are discussed. It is based on a paper given at the Sheet and Strip Metal Users' Technical Assoc. conference.—M. A. K.

On the Construction of Fatigue Diagrams for Asymmetric Cycles. M. P. Markovets. (*Zavodskaya Laboratoriya*, 1955, **21**, (3), 353–354). [In Russian]. A method for constructing fatigue diagrams from asymmetric cycle test-data is described which has been experimentally verified only for the initial part of the diagram, where stresses are below the yield-point value.—S. K.

Behaviour of Metallic Heaters in Endurance Tests. II. A. Schulze and D. Bender. (*Metall*, 1955, **9**, Oct., 878–882). In this paper results of tests of electric resistance elements are reported, relating to the influence of wire gauge on life of element as a function of temperature.—J. G. W.

Influence of Stress Gradient on Fatigue Limit. H.-O. Meuth. (*Metall*, 1955, **9**, Oct., 861–867). The author presents diagrams of the effective increase of fatigue limit against stress gradient for a range of form factors according to Neuben and Siebel, for a range of carbon steels and light alloys. The diagrams are based partly on data collated from literature and partly on the author's own investigations.—J. G. W.

The Effect of Time and Temperature on Various Mechanical Properties during Strain Ageing of Normalized Low Carbon Steels. F. Garofalo and G. V. Smith. (*Trans. Amer. Soc. Metals*, 1955, **47**, 957–983). The effects of ageing time and temperature on the strain ageing characteristics of three low carbon steels in the normalized condition have been investigated. Results are given for the effect on notch impact transition range, yield strength, tensile strength, and hardness.—E. E. W.

Recent Russian Work on Temper Brittleness. W. G. Cass. (*Iron Steel*, 1955, **28**, Oct., 467). This is a brief review of recent Russian work on the effect of carbide-forming elements, notably molybdenum and tungsten, on temper brittleness.

The Mechanism of Brittle Fractures. T. S. Robertson. (*Rev. Soudure*, 1955, **11**, (2), 85–90). [In French]. The author describes tests carried out on two mild steels of different chemical composition in order to determine the effect of grain size on brittleness. Evidence indicates that where grain size is predominantly small critical stress values are low whilst with predominantly large grains the critical stresses are higher. This gives experimental support for two possible explanations of brittle fracture.—M. D. J. B.

On the Temper Brittleness of Structural Special Steel. I. Irregularity of Temper Brittleness of Special Steel. H. Wakashima. (*Nippon Kinzoku Gakkai-Si*, 1953, **17**, Apr., 198–200). [In Japanese]. The degree of temper brittleness is greater in the inner than the outer part of ingots of Ni–Cr steel, although hardly any segregation of C, P, S, etc. can be detected. P greatly influences temper brittleness in this steel. Temper brittleness in low-P Ni–Cr, Cr, and Ni–Mn steels is much lower than in ordinary steels.—K. E. J.

Research Report on Brittleness of Metals. J. E. McLennan, S. T. M. Johnstone, and H. L. Wain. (*Australian Inst. Metals: Australasian Eng.*, 1955, Sept. 7, 67–75). The first section of this paper deals with ferrous alloys. A brief review is given of the factors which affect the temperature of the ductile–brittle transition as measured by the notched bend impact test. Recent work on the effects of grain size and of impurities both in solution and as second phases is discussed. (15 references). Sections two and three deal with chromium and molybdenum. Section four briefly reviews current theories of brittle–ductile transitions; it is concluded that the role of trace impurities is well worth further investigation. (10 references).—P. M. C.

Concerning the Use of Killed and Rimming Steel, Brittle Fracture, and Weldability of Steels. F.-C. Althof, H. Endter, G. Krüger, K.-F. Lüdemann, and R. Postl. (*Technik*, 1955, **10**, Oct., 589–604). Five papers by the above-named formed the subject of discussion at the Rostock University. The first contains a survey of recorded failures of bridges and ships caused by brittle fracture, leading to a diagnosis of the most frequent causes of failure, e.g. wrong choice of steel, faulty welding procedure, bad design. The second paper summarizes the metallurgist's recommendations as to the choice of steels, influenced by the need to increase the use of rimming steel in East Germany. In the third paper elements of ship construction are analysed from the point of view of the risk of brittle fracture. In the fourth the results of notch ductility tests of killed, rimming, and Bessemer steels are summarized and their suitability for fabrication discussed. The fifth paper deals with the effects of welding design and procedure on residual stresses.—J. G. W.

Brittle Fracture, with Special Reference to Liberty Ships. A. A. Wells. (*Eng. Insp.*, 1954, **18**, Autumn, 70–76). The characteristics of brittle fracture, the effect of temperature on type of fracture, the beneficial effects of high Mn/C ratio, and grain control by aluminium or silicon additions and by low finish-rolling temperatures are discussed. Two main types of fracture, those from faults in welds and those from zones which have suffered cold work, are described, and large scale plate testing techniques are considered. Current views on the mechanics of fracture initiation and propagation are expounded. (5 references).—P. M. C.

The Influence of Molybdenum and Tungsten on Temper Embrittlement. A. E. Powers. (*Trans. Amer. Soc. Metals*, 1955, **48**, Preprint No. 11). The influence of molybdenum and tungsten up to 2% on the susceptibility of a 1% chromium, 1% manganese steel has been studied. The steels were aged for 1000 hours at various temperatures within the temper embrittling region and the susceptibility to embrittlement was measured from the rise in the transition temperatures.—E. E. W.

Elementary Structures of Various Demagnetised Regions. G. Sommerkorn. (*Tech. Mitt. Krupp*, 1955, **13**, Aug., 71–83). The structure of various demagnetized conditions was investigated, using Bitter's method and the iron/silicon crystal containing 3·5% silicon. Permeability and crystal angles vary with the method of demagnetization. (19 references).—R. P.

On the Causes of Variations in the Permeability of Iron–Silicon Monocrystals by Means of Cooling in the Magnetic Field. H. Fahlenbrach. (*Tech. Mitt. Krupp*, 1955, **13**, Aug., 84–95). Hysteresis curves were obtained with and without cooling of the magnetic field and the structure observed by means of the Bitter–Williams' method. The permeability is shown to increase by cooling of the field. (10 references).

The Production and Magnetic Properties of C-Cores. F. Ackermann. (*Tech. Mitt. Krupp*, 1955, **13**, Aug., 98–103). The production of C-cores is described, followed by a discussion of their properties, advantages and limitations.—R. P.

Measurement of the Magnetic Properties of Open Test-Pieces. G. S. Veksler. (*Zavodskaya Laboratoriya*, 1955, **21**, (1), 71–74). [In Russian]. The determination of magnetic properties in the quality-control of ferromagnetic metals and alloy products is discussed with special reference to the use of open test-pieces.—S. K.

A Study of Domain Structures in Alnico. L. F. Bates and D. H. Martin. (*Proc. Phys. Soc.*, 1955, **B, 68**, Aug. 1, 537–540). Domain structures have been studied by the Bitter figure technique in polycrystalline specimens of Alnico (Al 10, Ni 18, Co 12, Cu 6, and Fe 54%) having coercivities of 0–100 oersteds. In low-coercivity specimens the domains are bounded by comparatively straight walls, but they show more irregular outlines in high-coercivity specimens; reasons for the difference are discussed.—K. E. J.

The Remanent Magnetization of Haematite Powders. E. P. Wohlfarth. (*Phil. Mag.*, 1955, **46**, Nov., 1155–1164). In connection with the magnetic properties of rocks, calculations are given for haematite (α–Fe_2O_3) powders of magnetic properties as functions of field strength, based on particles of single domains and magnetocrystalline anisotropy.—K. E. J.

The Problem of Magnetisation Reversal Losses in Transformers. F. Lihl. (*Radex Rundschau*, 1955, May/June, 460–472). [In German]. The physical principles underlying magnetization reversal losses are surveyed. The characteristics and properties of metals used for transformer cores are discussed and the effects of various types of heat-treatment are considered. The relationships between crystalline structure and magnetic behaviour are traced in detail, and further improvements in transformer steels are urged.—E. C.

Domain Structures Suggest Key to Enigma of Magnetic Force. C. D. Graham, Jun. (*J. Met.*, 1955, **7**, Sept., Section 1, 948–951). The author indicates that study of domain structure and domain boundary motions under various conditions can

be of value in understanding, predicting, and controlling the properties of magnetic materials. Variables which might be studied by observation of domains are the effects of textures, grain size, inclusions, internal stresses, and magnetic annealing.

The Metallurgy of Electrical Sheets for Magnetic Circuits. E. Marks. (*Proc. Staff. Iron Steel Inst.*, 1946–53, **61**, 30–42). The development of special alloy steels for use in electrical transformers is discussed. The properties of silicon steel are described and the influence of impurities on the magnetic properties are considered. The most spectacular recent improvement in transformer steel has been the introduction of cold rolled orientated grades.—B. G. B.

Stainless Steels. J. Apraiz. (*Bol. Min. Indust.*, 1955, **34**, Mar., 117–124). [In Spanish]. The various types of austenitic steels are described with particular reference to the 18-8 alloy and the effect upon its properties and uses of small percentages of carbon, phosphorus, titanium, tungsten, etc. The thermal treatment of austenitic stainless steel is described and comparison of its properties with those of other stainless steels is made in various tables. A short description of valve steel is also given.—J. R. P.

New Tough High Strength Steel Cuts Fabrication Cost. J. B. Campbell. (*Mat. Methods*, 1955, **41**, Jan., 102–106). The properties and possible applications of a new and versatile constructional plate steel, developed by United States Steel Corp., are reviewed. The steel, designated USS T-1, is supplied as plate in the thickness range $\frac{1}{4}$ to 6 inches to meet a minimum tensile strength specification of 105,000 psi (yield 90,000 psi) after quenching and tempering. A typical composition is 0·15% C, 0·75% Mn, 0·24% Si, 0·85% Ni, 0·50% Cr, 0·45% Mo, 0·05% V, 0·31% Cu, 0·003% B, sulphur and phosphorus below 0·03%.—P. M. C.

Suitability of Quenched and Tempered Steels for Pressure-Vessel Construction. L. C. Bibber. (*Welding J.*, 1955, **34**, Sept., 449s–464s). The amount of ductility needed for fabrication and operation, elastic ratios, relationship between ductility and toughness, the necessity for stress relieving are discussed. A destructive test used for 8 pressure vessels is described.—U. E.

The Properties and Characteristics of a Quenched and Tempered Steel for Pressure Vessels. W. D'Orville Doty. (*Welding J.*, 1955, **34**, Sept., 425s–441s). The properties of a new steel suitable for pressure vessels were investigated. It was found that the yield strength is at least 90,000 psi, and the material has good low-temperature notch-toughness. The fatigue strength, though low, can be improved by a combination of stress relieving and peening and also by removal of weld reinforcements.—U. E.

Precipitation Hardening in Low-Alloy Boiler Steels. F. Králík. (*Hutnické Listy*, 1955, **10**, (9), 525–528). [In Czech]. Heat treatment and the mechanism of precipitation hardening in Cr–Mo, Cr–V, and Cr–Mo–V are discussed on the basis of a number of experiments. The improvement of creep strength in boiler steels associated with the presence of vanadium is shown to derive from its high dispersion, the low tendency to spheroidization of vanadium carbide, the increase in the instability of cementite, which leads to an enhanced stability of the initial structure of the metal and, finally, from the increase in the creep-strength of ferrite if vanadium is in solid solution.—P. F.

Testing of Materials at the VEB Leunawerke "Walter Ulbricht." A. Wyszomirski. (*Neue Hütte*, 1955, **1**, Oct., 22–38). Strength of materials, particularly of steel exposed to hydrogen at high pressures, materials containing hydrogen and nitrogen, materials testing, heat treatment, fatigue and corrosion failure, and the high-temperature characteristics of steels are discussed.—L. J. L.

Development of, and Acceptance Testing Procedures Against Specifications. A. W. F. Green. ('*Utilization of Heat Resistant Alloys*': *Amer. Soc. Met., Symposium*, Mar. 11–12, 1954, 266–271). The author briefly details the general principles to be followed in the development of specifications and indicates some of the difficulties involved. The more commonly provided practices and procedures often called for in specifications as applied to heat-resistant materials are listed under the headings of composition, physical properties, and quality determinants.—D. H.

The Quality of Steel. A. Portevin. (*Inst. Hierro Acero, Special Number*, 1955, **8**, Oct., 541–568). [In Spanish]. The quality of a steel is defined as its ability to carry out its destined function in the best and most economical way. The many factors which influence quality are discussed. (34 references).—P. S.

Variation of Elastic Wave Velocity with Frequency in Fused Quartz and Armco Iron. D. S. Hughes and J. M. Kennel. (*J. Appl. Phys.*, 1955, **26**, Nov., 1307–1309). Velocity dispersion in fused quartz and in Armco iron has been investigated by measuring the resonant frequency of small cylinders, using quartz crystals in the ends as drivers and detectors. Differences were obtained with various cut crystals. With the transmission of torsional waves only and viscous coupling between the sample and the crystals, the velocity of Armco iron was found to be constant within $\pm$ 2 m/s in the range 0·5–1·5 Mc/s and decreased by about 10 m/s in the range 1·5–3·0 Mc/s.—E. E. W.

Creep and Static Friction. R. T. Spurr. (*Brit. J. Appl. Phys.*, 1955, **6**, Nov., 402–403). The static friction between a soft-metal hemisphere and a flat surface which increases with time of contact is attributed to creep.—E. E. W.

Significance of the Testing of Materials in Technology and National Economy. M. Pfender. (*Z.V.d.I.*, 1955, **97**, Sept. 21, 937–944). The president of the Federal German Mechanical and Chemical Materials Testing Institution states the function of materials testing, describes the present German organization of testing, and concludes with brief accounts of selected current investigations, most of which relate to non-metallic materials.—J. G. W.

Studies on the Hot-Working Strength of Steels. III. Rupture Characteristics. K. Inouye. (*Tetsu to Hagane*, 1955, **41**, Aug., 869–876). [In Japanese]. From studies of stress/strain curves and elongations, the characteristics of high-temperature high-speed deformation of various steels were elucidated; the $\gamma \rightarrow \alpha$ (900° C) embrittlement was clarified. From high-speed tension tests carried out between 1250° C and the melting point, it was found that deformation resistance decreased uniformly with temperature up to the melting point.—K. E. J.

The Formation of Cracks in Plastic Flow. II. A. N. Stroh. (*Proc. Roy. Soc.*, **A**, 1955, **232**, Nov. 22, 548–560). A model is developed to explain crack-formation through interactions of dislocations at the head of a pile-up. Stress relief by slip instead of fracture is considered. A crack may equally well be initiated by a smaller number of dislocations in several slip planes; this is important in ductility studies. (15 references).—K. E. J.

On the Change of the Modulus of Rigidity in Steel Wire Caused by Heat Treatments. H. Yamamoto and H. Takei. (*Nippon Kinzoku Gakkai-Si*, 1953, **17**, Apr., 161–164). [In Japanese]. Experiments were made with steel wires containing 0·58 and 1·02% C. The modulus of rigidity was increased substantially by annealing in the range 150–350° C. In quenched wire it was increased by tempering, particularly in the range 250–400° C. With austempering treatments, the maximum in the modulus was obtained by treatment at about 600° C, the minimum at 100–250° C.—K. E. J.

The Problem of Minimum Values for Elongation and Yield Strength in Rolled Products. S. Kronmarck. (*Metallurgie*, 1955, **5**, July, 212–214). Mechanical data obtained during rolling of bar steel are evaluated in the interests of standardization of constructional steels. The relation between elongation and tensile strength and the dependence of yield strength on bar diameter are investigated.—L. J. L.

Determination of the Resistance to Deformation of Metals. D. I. Suyarov, M. A. Benyakovskiĭ, and N. P. Skryabin. (*Zavodskaya Laboratoriya*, 1955, **21**, (1), 97–99). [In Russian]. In the technique described, the resistance to deformation of metals is found by compression tests on cylindrical specimens whose bearing surfaces are provided with anti-friction layers. Data calculated from such tests are shown to agree well with those of tensile tests for an alloy steel.—S. K.

Influence of Temperature on the Poisson's Ratio of High Temperature Steels. L. Raymondin. (*Métaux-Corrosion-Indust.*, 1955, **30**, Mar., 93–104). Absolute and indirect methods measuring Poisson's ratio are first considered and then a description is given of the Kirchoff method as used by the author, in which the sample is subjected to torsion and flexion simultaneously. Samples of high-temperature steels have been studied up to 800° C. The value of Poisson's ratio was found to vary inversely very slightly with temperature. The importance of the results is discussed.—B. G. B.

Application of Cottrell's Theory of Yielding to Delayed Yield in Steel. J. C. Fisher. (*Trans. Amer. Soc. Metals*, 1955, **47**, 451–462). The author analyses the Cottrell yield-point

mechanism and gives a quantitative description of the delayed-yield phenomenon as observed in steels. The temperature dependence of the yield stress is also calculated and found to be in the form: (stress) × (temperature) equals a constant, which agrees with results found in practice.—E. E. W.

Examination of Microstructures Under Varying Stress. R. A. Flinn and P. K. Trojan. (*Metal Progress*, 1955, **68**, July, 88–89). A short description is given of a bend-test apparatus that permits continuous microscopical examination of metal specimens while they are being loaded to fracture.

Determination of the Modulus of Elasticity for Torsioned Vibrations. V. I. Makarova. (*Zavodskaya Laboratoriya*, 1955, **21**, (3), 354–355). [In Russian]. The simple method described for the determination of moduli of elasticity is based on the measurement of the number of torsional oscillations executed in a given time. Values obtained for steel test-pieces are given.—S. K.

The Effect of Torsional Overstrain Upon the Static Strength of Spring Steel. J. A. Pope and J. E. Andrew. (*Inst. Mech. Eng., Advance Copy*, 1955, Feb. 19). This article gives the results of an investigation into the effect of low-temperature heat treatment upon the static properties of a hardened and tempered 0·63% C spring steel which had been previously subjected to torsional overstrain. It is shown that the textural stresses may be relieved by low-temperature heat treatment without reducing the beneficial body stresses produced by the torsional overstrain. At large overstrains the textural stresses are so great that plastic deformation in the reverse direction takes place on unloading. Such deformations reduce the residual body stresses, and therefore the elastic-limit strength, after low-temperature heat treatment. To prevent the plastic deformation on unloading, the specimens should be given the low-temperature heat treatment before removal of the load. Tests on springs show that the results from torsion specimens are applicable to springs. An improvement of about 33% in the elastic-limit strength and 8·5% in the 0·1% proof stress is evident after low-temperature treatment. (14 references).—P. M. C.

Preferential Magnetisation obtained by Non-homogeneous Tension in Magnetostrictive Materials. E. Houdremont and O. Rüdiger. (*Tech. Mitt. Krupp*, 1955, **13**, Aug., 104–106). The authors show that heterogeneous tensions produced, for example, by rolling, give rise to preferential directions of magnetization. (10 references).—R. P.

Non-Destructive Testing. (*Metal Ind.*, 1955, **87**, Oct. 7, 306–308). Some of the equipment in regular use in the Matlock laboratory of Solus–Schall Ltd. is described. The laboratory operates a Non-Destructive Testing Service for industry. Various X-ray units and radioactive isotope sources for industrial radiography are described, together with ultrasonic and magnetic flaw-detection equipment.—P. M. C.

Metallurgy and Microradiography. R. Urlocker, J. W. Rutter, and W. C. Winegard. (*Canad. Metals*, 1955, **18**, June, 28–32; July, 20–23). The use of radiography for the study of metallurgical specimens is described. Factors affecting the performance of the technique, including the relationship between the absorption edge of the X-ray beam and the metal specimen and the grain size of the photographic emulsion, are considered.—B. G. B.

New Knowledge on the Non-Destructive Supersonic Testing of Materials. R. Pollman. (*Metalen*, 1955, **10**, Nov. 30, 471–473). [In German]. The author describes two non-destructive supersonic methods of detecting defects in materials, namely the impulse echo method, involving the time of reflection from the position of the defect, and the continuous radiation method in which the existence of a defect in the material undergoing test causes a reduction in the wave intensity.—F. R. H.

Ultrasonic Inspection Speeds Drive-Tubing Output. L. Adams. (*Metalworking Prod.*, 1955, **99**, Nov. 11, 1905–1907). High-speed, continuous production of tubing at General Motors steering-gear works at Saginaw, U.S.A., is facilitated by ultrasonic inspection using a 'Sperry Reflectoscope.'

Studies of Non-destructive Testing. (III). On the Electrified Particle Inspection. S. Yoshida and K. Tamura. (*J. Mech. Lab.*, 1955, **9**, May, 102–106). A spray gun for charging powder particles electrostatically is described and its performance in crack detection by the powder method examined. This was good provided atmospheric humidity was below about 60%, cracks as small as 0·2 μ being identifiable.—J. G. W.

An Electron Diffraction Apparatus with Three Lenses. S. Nagata, Y. Tomoda, and K. Saito. (*Techn. Rep. Osaka Univ.*, 1955, **5**, Mar., 9–16). An electron diffraction apparatus suitable for industrial application, is described; its resolving power is $1 \cdot 5 \times 10^{-4}$ cm and it yields shadow images with a magnification of about 1000.—J. G. W.

The Design and Operation of an X-Ray Diffraction Apparatus with a Geiger Counter. Y. Yoneda, K. Kohra, and T. Futagami. (*Mem. Fac. Eng. Kyushu Univ.*, 1955, **15**, (1), 165–179). A description is given of this apparatus constructed by the authors.—B. G. B.

A Low Temperature Attachment for an X-Ray Goniometer. R. G. Butters and H. P. Myers. (*Canad. J. Tech.*, 1955, **33**, Sept., 356–359). A simple low-temperature attachment for use with a Philips high-angle X-ray diffraction goniometer is described. Measurements between room temperature and liquid oxygen temperature can be made.—B. G. B.

Tube Wall Thickness Gauge with Selection of Backscattered γ-Radiations. J. L. Putman, S. Jefferson, J. F. Cameron, J. P. Kerry, and E. W. Pulsford. (*J. Sci. Instruments*, 1955, **32**, Oct., 394–398). This gauge distinguishes γ-rays scattered back from a thickness of metal from primary γ-rays, so designed that the need for screening is eliminated and a light-weight measuring head is possible. Constructional details, circuit diagrams, and applications of the instrument are described. It is particularly suitable for measuring tube-wall or plate thickness up to $\frac{7}{8}$ in. steel and for detecting corrosion pitting in tubes.—L. D. H.

The Use of Electrical Eddy Currents for the Study of Surface Layers. A. P. H. Jennings. (*J. Iron Steel Inst.*, 1956, **183**, Aug., 415–421). [This issue].

Non-Destructive Tests for Metal Parts. D. E. Brooks. (*Eng. Insp.*, 1954, **18**, Autumn, 54–56).

Life of Aluminized Steels at High Temperatures. P. Gröbner. (*Hutnické Listy*, 1955, **10**, (10), 600–605). [In Czech]. On the basis of a theoretical analysis, it is concluded that the high-temperature life of aluminized steel could be extended by decreasing the rate of diffusion of aluminium in the steel, i.e. by adding alloying elements such as carbon. This is confirmed by comparative experiments with iron and a 0·4% C steel. Aluminium in steel does not materially decrease the coefficient of diffusion of aluminium into the latter.—P. F.

Relaxation Tests on Metals at High Temperatures. A. Chitkov. (*Hutnické Listy*, 1955, **10**, (9), 521–525). [In Czech]. The paper represents the second and final instalment of the author's analysis of relaxation methods, their scope and relation to creep testing. Relaxation behaviour cannot, in general, be evaluated with the required accuracy from creep tests, and vice versa. The use of helical spring specimens stressed in torsion, of specimens in the form of flanged joints, split rings and rods with shoulders such as are used in tensile testing are considered, and the results obtained with them compared. The log stress versus time plot is shown to be most appropriate for the representation of relaxation behaviour in all cases.—P. F.

The Influence of Columbium (Niobium) and Titanium on Plastic Properties of Stainless and Heat-Resisting Steels at High Temperatures. N. S. Alferova. (*Stal'*, 1948, **8**, (10), 911–916). [In Russian]. Mechanical properties at high temperatures of stainless and heat-resistant steels stabilized with titanium and niobium were investigated. It was found that additions of titanium and particularly of niobium decrease the plasticity of heat-resisting steels in the hot state. Among hot-testing methods applied to tube steels, the torsion test is most indicative. Appropriate rolling temperatures for various steels are recommended.—V. G.

Steels and Alloys Resistant to Corrosion at Elevated Temperatures. L. Colombier. (*Métaux–Corrosion–Indust.*, 1955, **30**, July-Aug., 294–303). A comprehensive review of the properties of alloy steels suitable for use at high temperatures is presented. Iron base, nickel base, and iron–nickel base alloys are considered. Their resistance to oxidation is primarily considered although their resistance to nitrogen, hydrogen, sulphur gases, combustion gases, molten salts, and solid refractory materials are also considered.—B. G. B.

High Temperature Properties of Iron-Rich Fe–Mo Alloys. S. F. Reiter and W. R. Hibbard, Jun. (*Trans. Amer. Inst. Min. Met. Eng.*, 1955, **203**; *J. Met.*, 1955, **7**, May, Section 2, 655–663). The authors have surveyed the effect of heat treatment on room-temperature hardness of Fe–Mo alloys, and have carried out constant strain-rate tensile tests and

constant load creep-rupture tests, relating the results to the constitution diagram. The data have been analysed to determine the effect of temperature and composition on the strain-hardening coefficient and strain-rate sensitivity, and a relation between the high-temperature strength of the precipitation-hardened alloys and the volume of precipitate has been observed.—G. F.

The Properties of Steel at Elevated Temperatures—Review of Literature Published in 1952. A. Krisch. (*Stahl u. Eisen*, 1955, **75**, Mar. 24, 349–353; Apr. 7, 422–428; May 5, 599–604; May 19, 648–650). The author first reviews the following subjects: Changes in the Elastic Constants; Equipment for Creep Testing; Properties of Metals at Elevated Temperatures; Effect of Multi-Axial Stress and Notch Effects; Relief of Stresses. In the following parts the problems of Creep in Gas-Turbine blades and the 'Effect of Composition' are studied and in the concluding part the high-temperature properties of Grey Iron and Non-Ferrous Metals are included.

Inhibition by Nitrogen of Graphitization in Steel. G. V. Smith and B. W. Royle. (*Trans. Amer. Soc. Metals*, 1955, **48**, Preprint No. 17). An arbitrary heat treatment known to promote graphitization of cold-rolled, high-carbon steel strip, was inhibited by prior heating in an atmosphere of nitrogen for 6 h at 1040° C. The nitrogen content was increased from 0·005% to 0·013%. Heating in hydrogen for 2 h at 1040° C reduced the nitrogen to 0·003% and increased graphitization.

High Nitrogen Austenitic Cr–Mn Steels. V. F. Zackay, J. F. Carlson, and P. L. Jackson. (*Trans. Amer. Soc. Metals*, 1955, **48**, Preprint No. 5). High-nitrogen Cr–Mn austenitic steels were prepared by a pressure-melting and casting technique. Nitrogen contents of 0·5% and over were obtained. The creep-rupture properties of the base composition (16 Cr, 14 Mn, 2 Mo, ½ N) were approximately equivalent to those of 16–25–6 a commercial heat-resisting alloy. The unusually high interstitial nitrogen content resulted in excellent combinations of strength and ductility in both the annealed and cold-worked state.—E. E. W.

The Formation of Hydrogen Peroxide on Metals Subject to Stresses in Aqueous Media. V. Seifert, K. Smrček, J. Vorlíček, and I. Sekerka. (*Hutnické Listy*, 1955, **10**, (10), 595–600). [In Czech]. On the basis of experiments described, the authors conclude that the formation of hydrogen peroxide on iron as well as on glass is facilitated by ultrasonic pulses originating in slip.—P. F.

Some Effects of Silicon on the Mechanical Properties of High Strength Steels. C. H. Shih, B. L. Averbach, and M. Cohen. (*Trans. Amer. Soc. Metals*, 1955, **48**, Preprint No. 9). An improvement in high-strength mechanical properties was obtained in the two tested steels by increasing the silicon content to 1·5%. The effect on the various mechanical properties is given in a series of graphs. There is evidence that the fatigue endurance limits and the elastic limits may be related.—E. E. W.

Mechanical Properties of Iron–Chromium–Aluminium Ternary Alloys. I. I. Kornilov and V. S. Mikheev. (*Stal'*, 1946, **6**, (2), 99–104). [In Russian]. Curves for the hardness, tensile strength, and elongation of iron–chromium–aluminium ternary system as functions of chromium (up to 40%) and aluminium (up to 15%) contents as well as the curves for the impact strength of these alloys as a function of chromium (up to 25%) and aluminium (up to 8%) contents, and their temperature were established. The inter-relation between the ductility and the heat-treating temperature for some alloys was also established.—V. G.

Titanium in Iron and Steel. A. E. Williams. (*Iron Steel*, 1955, **28**, June, 307–310). The author discusses three main uses of titanium in iron and steel manufacture: (i) as an inoculant in cast iron; (ii) as a deoxidant in steelmaking; and (iii) as an alloying element in steels, particularly high-chromium heat-resisting steels. The effects of the additions and the correct addition procedures are described.—G. F.

New Stainless Steels Qualify for High-Temperature Service. E. A. Loria. (*Iron Age*, 1955, **176**, Sept. 29, 65–67; Oct. 13, 109–111). 'Crucible HNM' is a high carbon–chromium–manganese–nitrogen austenitic steel developed by Crucible Steel Company of America; its properties and suitable heat treatments are described. It has been used to replace nickel steels in rider sheet and other high-temperature applications.

Some Recent Developments in Stainless Steels. J. I. Morley. (*J. Bham. Met. Soc.*, 1955, **35**, June, 187–212). Strength-to-weight ratio, modulus of elasticity, and corrosion resistance are discussed with reference to materials (notably stainless steels) for structural use. Special consideration is given to the problems associated with sheet material for service at temperatures up to 300° C, for example, as high-speed aircraft skins. The metallurgy and treatment of the 11–13% Cr type steels, and precipitation hardening of 17% Cr, 7% Ni type steels are discussed in detail. (8 references).—P. M. C.

Stainless and Heat Resistant Alloys. V. N. Krivobok and E. N. Skinner. (*Metal Progress*, 1955, **68**, Sept., 118–122). The development of these steels over the last 25 years is discussed. Iron-, nickel- and cobalt-base alloys are assessed and some brief notes on high-temperature resistance are given.—B. G. B.

Carbon and Alloy Steels. M. W. Lightner. (*Metal Progress*, 1955, **68**, Sept., 93–97). A short review of the practical advances made in the past 25 years in the development of carbon and alloy steels is presented.—B. G. B.

Tool Steels. B. M. Hamilton. (*Canad. Metals*, 1955, **18**, July, 39–41; Aug., 52–55). An account of the properties of the tool steels available and their selection is presented.

The Work of the Central Works Laboratory of the Chelyabinsk Metallurgical Works. M. I. Kolosov. (*Zavodskaya Laboratoriya*, 1955, **21**, (3), 376–377). [In Russian]. The central works laboratory of the Chelyabinsk works is made up of laboratories dealing with (i) research on blast-furnaces, steel-making, rolling and metallurgy; (ii) routine control tests; (iii) chemical problems; (iv) by-product coking; (v) refractories. The general role of the works laboratory in the improvement of plant efficiency is considered and educational and inter-works activities are briefly indicated.—S. K.

METALLOGRAPHY

Surface Distributions of Dislocations in Metals. C. J. Ball and P. B. Hirsch. (*Phil. Mag.*, 1955, **46**, Dec., 1343–1352). A boundary containing dislocations of two systems can, in general, form on two planes only; the rotation axes are simple crystallographic directions. This concept explains much evidence of misorientation in deformed crystals. (17 references).—K. E. J.

The Role of Crystal Structure on Irradiation Effects in Metals. D. Wruck and C. Wert. (*Acta Met.*, 1955, **3**, Mar., 115–120). Neutron bombardment of iron and nickel at room temperature and deuteron bombardment of iron, nickel, and cobalt at − 150° C indicated that iron is affected more than the other metals.—A. D. H.

The Segregation of Carbon in Iron Single Crystals as Studied by Torsion Pendulum Damping. F. W. Kunz. (*Acta Met.*, 1955, **3**, Mar., 126–129). The effect of quenching and strain on the segregation of carbon was studied, using a torsion pendulum and carburized iron single crystals of high purity. The changes in damping during room temperature ageing could be explained on the basis of the Cottrell mechanism. After ageing at 115° C it was necessary to postulate an interaction between dislocations and precipitated carbide to explain the resolution of carbide once formed and the re-segregation of carbon at grain boundaries. A correlation was observed between damping and yielding during room temperature ageing.—A. D. H.

Grain Boundary Diffusion in a Body-Centred Cubic Lattice. C. W. Haynes and R. Smoluchowski. (*Acta Met.*, 1955, **3**, Mar., 130–134). Bicrystals of an iron–3% Si alloy having a common [011] direction were prepared by Dunn's method and plated with a radioisotope of iron so that its penetration at the grain boundary during diffusion could be followed by an autoradiographic technique. No preferential grain boundary diffusion was observed when the angle of disorientation between the crystals was $< 10°$. Penetration increased up to a disorientation of 86° with a minimum at $\sim 50°$.—A. D. H.

Frictional Forces on Dislocation Arrays at the Lower Yield Point in Iron. A. Cracknell and N. J. Petch. (*Acta Met.*, 1955, **3**, Mar., 186–189). The equation $\sigma = \sigma_0 + K^* l^{-\frac{1}{2}}$ which relates the lower yield point σ of polycrystalline iron with the grain diameter l was confirmed experimentally. K^* and σ_0 are constants. σ_0 was found to increase when the solute atom concentration was increased and a further increase occurred on ageing followed by a decrease on over-ageing. The value of σ_0 is considered to depend on the frictional forces exerted by solute atoms and precipitates on the dislocation arrays that propagate yielding. A predicted linear relationship between the dissolved (C + N) content and σ_0 was confirmed experimentally.—A. D. H.

Surface Examination by Reflection Electron Microscopy. J. S. Halliday. (*Inst. Mech. Eng., Advance Copy*, 1955, Apr. 15). The examination of surface profile by oblique viewing in an electron microscope is described. Several micrographs show that ground surfaces of comparable roughness may have different textures which are apparently related to the mechanical properties of the metals under examination. The range of surface finish which can be examined is illustrated by micrographs of electropolished aluminium (highest asperity being 0·4 micro-inch) and of ground tool steel (asperities up to 70 micro-inches). Applications of the technique to the examination of surface damage by wear processes is discussed. (14 references).—P. M. C.

Metallurgical Aspects of Microscopy. B. W. Mott. (*Research*, 1955, **8**, Aug., 307–313). A review is made of recently-developed techniques, including phase-contrast and polarized-light microscopy, interferometry, and examination of radioactive metals. (42 references).—K. E. J.

An Improvement in Replica Technique for Electron Microscopy of Structures in Steel. H. Modin. (*Jernkontorets Ann.*, 1955, **139**, (8), 521–523). [In English]. To prevent interference by adherent cementite particles, the film stripped from the sample is placed in dilute sulphuric, hydrochloric or nitric acid (1 : 20) until the carbide particles are dissolved. The plastic film is not damaged, but must be washed for about an hour before drying.—G. G. K.

Phase-Contrast in Microscopy. R. Parés Farrás. (*Rev. Ciencia Apl.*, 1955, **9**, Jan.-Feb., 19–30). [In Spanish]. The general theory of phase-contrast microscopy is discussed, and the principles of the various techniques available are explained.

The Sensitivity of Electron Diffraction as a Means of Detecting Thin Surface Films. I. R. C. Newman and D. W. Pashley. (*Phil. Mag.*, 1955, **46**, Sept., 927–950).

The Microstructure of Polycrystalline Materials. C. S. Smith. (*Trans. Chalmers Univ. Tech. Gothenburg*, 1954, (152), 49). Factors controlling the microstructure of alloys are considered in detail.—B. G. B.

Effect of Nitrides on the Coercive Force of Iron. J. Kerr and C. Wert. (*J. Appl. Phys.*, 1955, **26**, Sept., 1147–1151). The maximum effect on the coercive force of iron was found to be produced by particles whose largest dimension was of the order of the domain wall thickness. The results are in good agreement with the effects produced by carbides.

Permanent-Magnet Properties of Elongated Single-Domain Iron Particles. L. I. Mendelsohn, F. E. Luborsky, and T. O. Paine. (*J. Appl. Phys.*, 1955, **26**, Oct., 1274–1280). The predicted and observed properties of crystal anisotropy fine-particle magnets are reviewed and compared with an ideal fine-particle iron magnet based on the shape-anisotropy model of Stoner and Wohlfarth. The effect of particle alignment and packing fraction on magnetic properties is described and energy products above 3,000,000 gauss-oersteds are reported.

Shape and Crystal Anisotropy of Alnico 5. E. A. Nesbitt and H. J. Williams. (*J. Appl. Phys.*, 1955, **26**, Oct., 1217–1221). Torque measurements on single crystals of Alnico 5 indicate that the high coercive force of these crystals depends on the shape anisotropy of the fine precipitated plates and that their crystal anisotropy is negligible. The peak values of torque which decrease with increasing field are shown to be due to shape anisotropy and the peak values of the curves extrapolate to zero for infinite field indicating that the alloy has zero crystalline anisotropy.—E. E. W.

On the Recrystallization Diagram. G. G. Kromrey. (*Neue Hütte*, 1955, **1**, Oct., 46–52). Definitions are given of solidification, crystal structure, relaxation, etc., the recrystallization process, formation of seed crystals, crystal growth, the Czochrolski diagram, and crystal decay are described; the recrystallization diagram is discussed.—L. J. L.

The Electron Microscope and the Polished Metal Surface. E. Brüche and H. Poppa. (*Metalloberfläche*, 1955, **9**, Sept., A129–A135). The principle of the electron microscope and its advantages over the optical microscope (including high resolving power combined with great depth of focus) are described, the technique of preparing replicas is outlined, and an example of the use of the instrument in studying the polishing of metals is given.—L. D. H.

Contribution to the Study of Metal Structures by the Electron Microscope. G. Bonfiglioli and A. Ferro. (*Met. Ital.*, 1955, **47**, Sept., 409–414). [In Italian]. Examples are given of the practical application of the electron microscope in metallographic studies. The advantages of the electron over the optical microscope are discussed and some 20 photographs are given illustrating the greater detail of metal structure obtainable. (6 references).—M. D. J. B.

I. Depth Hardening of Steel. II. The Examination of Steel under the Electron Microscope. F. van Wijk and J. A. B. van Dijck. (*Metaalinstituut TNO*, Publ. 28, 1955, Jan., 1–6, 7–12). [In Dutch]. In the first paper a concise survey is given of the theory of depth hardening of steel with a discussion of the factors of hardenability, quenching, and dimensions of the work piece. The need for a good method for assessing hardness values is emphasized and that of Lamont is cited as an example. The second paper discusses the results of an investigation of structures in heat-treated steels and cold-deformed troostite examined under an electron microscope. Several micrographs are shown.—F. R. H.

Thermal Changes in Steels as shown by Resistivity. G. Bullock. (*J. Iron Steel Inst.*, 1956, **183**, Aug., 362–367). [This issue].

Domain Configurations and Crystallographic Orientation in Grain-Oriented Silicon Steel. W. S. Paxton and T. G. Nilan. (*J. Appl. Phys.*, 1955, **26**, Aug., 994–1000). A semi-quantitative relationship has been found between domain patterns and crystalline orientation. The magnetic domain structure of polycrystalline 3¼% silicon steel was investigated by the magnetic powder pattern technique and the orientation of individual grains determined by the etch-pit optical goniometer technique.—E. E. W.

A Method for the Measurement of Elastic Relaxation, and its Use for Determination of Carbon in Iron. E. Lindstrand. (*Acta Met.*, 1955, **3**, Sept., 431–435). A new method employing a helically coiled specimen is described. The specimens are so large that the carbon in solution can be determined by direct weighing after carburization. The apparatus was used to determine the solubility of carbon in α-iron. The solubility between 400° and 700° C differed from that obtained by torsion pendulum and calorimetric methods.—A. D. H.

Determination of Cementite in the Presence of the Carbides of Vanadium and Molybdenum. N. M. Popova, A. F. Platonova, and L. V. Zaslavskaya. (*Zavodskaya Laboratoriya*, 1955, **21**, (1), 22–24). [In Russian]. An account is given of an improved procedure for cementite determination in alloy steels containing carbides of vanadium and molybdenum. After electrolytic separation, the carbide residue is collected and treated in several portions, enabling corrections to be made for losses in the production and washing of the precipitate. The method was tested on two steels (0·4% C, 2% V, and 0·4% C, 2% Mo respectively), subjected to various heat treatments. The results agreed well with those of chemical analysis, and X-ray analysis showed the completeness of the separation of carbides.—S. K.

The Temperature of Formation of Martensite and Bainite in Low-alloy Steels. Some Effects of Chemical Composition. W. Steven and A. G. Haynes. (*J. Iron Steel Inst.*, 1956, **183**, Aug., 349–359). [This issue].

Hardness of Tempered Martensite in Carbon and Low-alloy Steels. R. A. Grange and R. W. Baughman. (*Trans. Amer. Soc. Metals*, 1955, **48**, Preprint No. 12). The hardness of martensite in a number of plain carbon and alloy steels, after tempering for various combinations of temperature and time, is given and the data are compared to show the effect of carbon and alloying elements. The authors have developed an empirical method for estimating, within limits, the hardness of tempered martensite from the chemical composition.

Identification of Microconstituents in Alloys. R. Nordheim. (*Tidsskr. Kjemi, Bergvesen Met.*, 1955, **15**, (2), 29–34). [In Norwegian]. The author reviews methods now in use for this purpose, especially concentration of the microconstituents by chemical and electrolytic isolation together with selective etching of polished alloy test samples. Examples are given of the method of identifying microconstituents in steel, in Ni–Cr–Co alloys, and in light alloys. Finally chemical methods of analysis are discussed.—G. G. K.

A Method for Isolating Carbide in Carbon and Low Alloy Steel. H. Modin. (*Jernkontorets Ann.*, 1955, **139**, (8), 516–520). The ferrite is dissolved in nitric acid (1 : 1) for periods ranging from 7 to 20 seconds, washed in distilled water twice, and immediately transferred to absolute alcohol. After washing again in alcohol the sample is placed in *iso*amyl acetate, washed two or three times, and the carbides finally scraped off. Electron microscope study shows that the carbide is not noticeably attacked during extraction.—G. G. K.

The Isothermal Transformation Characteristics of Carburized 2% Nickel–Molybdenum Steel. G. Mayer and R. H. Hickley. (*Metallurgia*, 1955, **52**, Nov., 236–239). Isothermal transformation diagrams representing the core and four positions in the case have been determined. Variations in austenitizing temperature, in the range 770–915° C, produces no change in the isothermal transformation diagrams of the core and case (at 0·84% C). The mechanical properties of steels of typical core composition are included.—B. G. B.

On the Isothermal Transformation Treatment and its Application [to] High-Carbon, High-Chromium Steel. S. Koshiba and T. Nishimura. (*Nippon Kinzoku Gakkai-Si*, 1953, **17**, Apr., 165–167). [In Japanese]. The optimum heat treatment for a magnet steel was determined from the isothermal transformation diagram. The structure after normalizing from 1150° C is almost entirely austenitic, and is stable for a holding time of 8 h below 400° C. The best preheating temperature before quenching is 650–700° C.

Effect of Carbon, Arsenic, Copper and Tin on Transition Temperature of Steel. H. Sawamura, T. Mori, and K. Fujita. (*Tetsu to Hagane*, 1955, **41**, Aug., 861–869). [In Japanese]. The effects of As, Cu, Sn, and Mo on the transition temperature of dead-soft steel, and of C and As on that of carbon steel, were investigated by Charpy tests at temperatures between − 80° and 400° C. C raised the fracture transition temperature. As raised this temperature, but not in amounts $< 0{\cdot}1\%$, alone or with Cu and Sn. Cu ($< 0{\cdot}35\%$) had no effect alone or with Sn and As; Sn ($< 0{\cdot}1\%$) similarly, alone or with Cu and As. N lowered the temperature when present as AlN, but otherwise raised it.—K. E. J.

Effect of Al, Ti and B addition on the Impact Transition Characteristics of High-Strength Cr–Mo Steel as Tempered at Low Temperature. T. Kawai, Y. Masuko, and M. Nishida. (*Tetsu to Hagane*, 1955, **41**, Aug., 877–880). [In Japanese]. The effects of treatment with Al (*a*), Al–Ti (*b*), and Al–Ti–B (*c*) were investigated. All treatments, particularly (*c*), improved impact values at 100–450° C tempering temperature. The temperature of temper-brittleness was unchanged by (*a*), but raised to ∼ 350° C by (*b*) or (*c*). For each treatment, the transition temperature apparently varied with the tempering temperature. All treatments lowered the transition temperature, particularly (*b*) and (*c*) in the 300–350° C range of tempering embrittlement. These treatments are therefore valuable in obviating brittle fracture in finished products.

Microscopical Investigation of the Formation Process of Martensite (30% Ni–Fe Alloy). M. Okada and Y. Arata. (*Techn. Rep. Osaka Univ.*, 1955, **5**, Mar., 169–176). The change in surface structure of electrolytically polished specimens of 30% Ni–Fe alloy, resulting from ' stabbing ' by means of a needle, were examined microscopically. From the photographs obtained and reproduced in the paper, various features of the mechanism of martensite formation were inferred.

Measures for the Prevention of Coarse Carbide Segregation in High-Speed Steels. K. Werner. (*Metallurgie*, 1955, **5**, Aug., 252–258). As a result of a study of the literature, experiments, and statistical analyses of a number of high-speed steel melts, suggestions for the prevention of carbide segregation are made. These include the use of clean high-speed steel scrap, the addition of ferro-tungsten, a tapping temperature above 1580° C, repeated stirring, casting at 1450° C, casting speeds between 30 and 40 in./min, and at least 10-fold deformation.

On Banding in Steel. C. F. Jatczak, D. J. Girardi, and E. S. Rowland. (*Trans. Amer. Soc. Metals*, 1955, **48**, Preprint No. 20). Transformation studies on five types of steel after homogenization treatments at 1200° C indicated that chemical heterogeneity is the primary cause of banding. Steels which contain primarily carbide-forming elements homogenize more readily than those containing primarily solution-type elements. Comparison is made of the physical properties of a steel in the banded and homogenized conditions.—E. E. W.

Effect of Boron on the Relative Interfacial Tension of Gamma Iron. A. M. Adair, J. W. Spretnak, and R. Speiser. (*Trans. Amer. Inst. Min. Met. Eng.*, 1955, **203**: *J. Met.*, 1955, **7**, Feb., Section 2, 353–354). Using a technique of heat-etching in vacuum, the authors have studied the effect of boron on the interfacial energy of austenite grain boundaries. The results indicate that boron reduces the interfacial energy, but not sufficiently to explain the hardenability effect directly on this basis.—G. F.

Influence of Heat Treatment on the Ductile–Brittle Transition Temperature of Semikilled Steel Plate. R. H. Frazier, F. W. Boulger, and C. H. Lorig. (*Trans. Amer. Inst. Min. Met. Eng.*, 1955, **203**; *J. Met.*, 1955, **7**, Feb., Section 2, 323–329). Using semi-killed steel plate, the authors have established the effect on transition temperature of the ferrite grain size resulting from different austenitizing temperatures and cooling rates. ' Navy ' tear tests and ' keyhole Charpy ' tests give transition temperature values not fully comparable and not equally affected by heat-treatment variations.—G. F.

Curie Temperatures of Binary and Ternary Sigma Phases. M. V. Nevitt and P. A. Beck. (*Trans. Amer. Inst. Min. Met. Eng.*, 1955, **203**; *J. Met.*, 1955, **7**, May, Section 2, 669–674). The authors have found that all binary and a number of ternary alloys formed by the first long period transition elements are ferromagnetic at low temperatures, their Curie temperatures being correlated with composition in a manner described qualitatively in terms of the contributions of the various component atomic movements to the alloy's saturation moment. The Curie temperature is dependent on iron content in Fe–Cr–Mo σ alloys, and on Co + Fe contents in Co–Fe–Cr and Co–Cr–Mo σ alloys, being largely independent of the unit cell dimensions.—G. F.

Relation between the Alpha and Sigma Phases in Austenitic Mn–Cr Steels, and Differentiation between them by Means of Magnetic Suspensions. V. Havel and M. Zezulová. (*Hutnické Listy*, 1955, **10**, (7), 400–403). [In Czech]. The occurrence and distribution of the phases, the reversibility of the alpha–sigma transformation, and the use of the magnetic suspension method for distinguishing between them were studied. The σ-phase was found to preserve both the form and the distribution of the α-phase.—P. F.

On Two Types of Pearlitic and Ferritic Reactions in Alloy Steels. J. Čadek. (*Hutnické Listy*, 1955, **10**, (7), 409–413). [In Czech]. The kinetics of the isothermal reaction leading to Hultgren's so-called ' parapearlite,' and the low-temperature pearlitic reactions were studied thermo-magnetically. Hultgren's postulate of this pearlite is challenged on the basis of the results obtained. Low-temperature pearlite formation is shown to occur by other processes than at high temperatures. The amount of low-temperature pearlite formed depends on the temperature of formation, showing a maximum at a certain temperature. A new type of low-temperature ferritic reaction was observed to occur at about the same temperature as the low-temperature pearlitic reaction, preceding the latter. The amount of low-temperature ferrite formed also depends upon the temperature and also has a maximum. The mechanism of initiation of this reaction remains obscure. The isothermal decomposition of austenite in many alloy steels was found to be a complex process consisting, in a given range of temperatures, of as many as five reactions occurring as a sequence, the later stages being related to those immediately preceding them.—P. F.

Application of Gibbs-Duhem Equations to Ternary Systems. R. Schumann, jun. (*Acta Met.*, 1955, **3**, May, 219–226). A general solution of the Gibbs–Duhem equation is presented for ternary systems using a new method which leads to the derivation of a relationship between the tangent intercepts of isoactivity curves for the various components. Activity calculations for ternary slags composed of FeO, Fe_2O_3, and SiO_2 are presented to illustrate the application of the derived relationships.—A. D. H.

The Heats of Formation in the Systems Titanium–Aluminium and Titanium–Iron. O. Kubaschewski and W. A. Dench. (*Acta Met.*, 1955, **3**, July, 339–346). Using a calorimeter, the exothermic heats of alloying were determined in the systems Fe–Al, Ti–Al, and Ti–Fe. The probable errors are considered to be $1{\cdot}5$–$2{\cdot}5\%$.—A. D. H.

The Enthalpy of Pure Iron. J. R. Pattison and P. W. Willows. (*J. Iron Steel Inst.*, 1956, **183**, Aug., 390–403). [This issue].

CORROSION

Elements of Corrosion Control. C. L. Crockett. (*J. Amer. Water Works Assoc.*, 1955, **47**, Apr., 355–358). The author first introduces briefly the principles and types of corrosion, then outlines the various corrosion control methods, and concludes with a description of typical corrosion problems encountered by the Norfolk and Western Railway and the steps taken to overcome them.—L. E. W.

Wear and Corrosion in Mines. J. Dolan. (*J. S. African Inst. Mech. Eng.*, 1955, **4**, June, 367–438). The operating conditions in and production data for the Witwatersrand mines

are detailed and discussed in relation to wear and corrosion. It is concluded that wear is the more vital problem.—L. E. W.

Fretting Corrosion on a Screwed Joint Under Prolonged Fatigue Loading. J. E. Field. (*Engineer*, 1955, **200**, Aug. 26, 301–302). Fretting corrosion can considerably reduce the inherent fatigue resistance of a part subjected to fluctuating stresses. The author describes tests of fretting corrosion on a screwed connection and shows that the fatigue strength of a bolt is not adversely affected.—M. D. J. B.

Human Body Fluids Affect Stainless Steel. C. A. Zapffe. (*Metal Progress*, 1955, **68**, July, 95–98). An account of a number of cases in which stainless steel parts used in bone fixing and in contact with perspiration have failed in service, is presented.—B. G. B.

The Evaluation of Corrosion Resistance for Gas Turbine Blade Materials. W. E. Young, A. H. Hershey, and C. E. Hussey. (*Trans. Amer. Soc. Mech. Eng.*, 1955, **77**, Oct., 985–993). Surface analysis of gas turbine blade material before and after exposure to combustion products of residual fuel oils gives a measurable indication of corrosion in a shorter time than is required to produce appreciable weight loss. Weight loss measurements following long time tests have shown close agreement with this method of analysis. The fusion temperature of the fuel ash appears to be a reliable criterion for judging the potential corrosivity of residual fuel oil and good agreement has been obtained between ash-fusion temperatures and corrosion both for untreated and treated oils.—D. H.

The Corrosive Nature of Combustion Gases from Carbon Monoxide Flames containing Sulphur Oxides. G. Whittingham. (*J. Appl. Chem.*, 1955, **5**, July, 316–322). Corrosion of iron, by flue gases of relatively low moisture content from a diffusion flame of carbon monoxide to which additions of sulphur dioxide had been made, is greatest at 66° to 70° C. The humidity of the combustion air also affects corrosion. The percentage conversion of sulphur dioxide to sulphur trioxide and the rates of acid build-up were also investigated.

Further Investigations into the Corrosion of a Steel Surface by Condensed Films of Sulphuric Acid. R. W. Kear. (*J. Appl. Chem.*, 1955, **5**, June, 260–266). Further experiments on the corrosion of steel by flue gases containing sulphur dioxide and sulphur trioxide show that for tests up to 24 hours there is a reduction in the rate of corrosion after 8 hours and that in the presence of corrosion products, the corrosion continues even when the temperature of the metal is raised to or above the acid dew-point temperature.—E. E. W.

Tests on the Relative Efficiency of Chromate Pigments in Anticorrosive Primers. H. G. Cole. (*J. Appl. Chem.*, 1955, **5**, May, 197–208). Under sea-water spray corrosion tests, strontium chromate priming paint in stand oil/coumarone medium proved the best of seventeen chromate pigments when used on mild steel and on three non-ferrous alloys. Fair to good protection was afforded by five other chromates.

The Effect of Hydrochloric Acid on the Corrosive Nature of Combustion Gases containing Sulphur Trioxide. R. W. Kear. (*J. Appl. Chem.*, 1955, **5**, May, 237–242). The effect on mild steel of hydrogen chloride and chlorine additions to town gas fuel containing sulphur oxides was to increase the corrosion by some 40%. Below the water dew-point temperature a very large increase in corrosion was found and this was generally accelerated by the addition of hydrogen chloride and chlorine.

The Formulation of Priming Paints for Structural Steel. J. C. Hudson and J. F. Stanners. (*J. Appl. Chem.*, 1955, **5**, Apr., 173–188). The properties desirable in priming paints are discussed. The interim results of tests on such paints show that for weathered steel the best medium is linseed oil and that one of the best pigments is a mixture of red lead, white lead, and asbestine. Good results have also been obtained from priming paints pigmented with aluminium powder, basic lead sulphate or zinc oxide, with or without extender, in alkyd medium, and by pigmented paints derived from gilsonite and various drying oils.—E. E. W.

Air Injection for Prevention of Hydrogen Penetration of Steel. W. A. Bonner and H. D. Burnham. (*Corrosion*, 1955, **11**, Oct., 49–55). Hydrogen damage to steel in contact with hydrogen sulphide can be prevented by injecting air into the hydrogen sulphide. The difficulties overcome and the control methods are described.—J. F. S.

Microbiological Corrosion of Iron and Steel. D. M. Updegraff. (*Corrosion*, 1955, **11**, Oct., 44–48). A critical review of the literature on microbiological factors involved in the corrosion of iron and steel is presented.—J. F. S.

Basic Essentials for the Reduction of Atmospheric Corrosion. F. Radecke. (*Corrosion*, 1955, **11**, Oct., 39–43). A successful maintenance painting programme for a refinery has resulted from the preparation of a policy manual, the selection of suitable painting schemes and methods of surface preparation, insistence on adequate paint film thickness and thorough supervision. A typical paint specification is given.—J. F. S.

The Effect of Martensite on Sulphide Stress-Corrosion Cracking. M. F. Baldy and R. C. Bowden, Jun. (*Corrosion*, 1955, **11**, Oct., 19–24). Rapid failures of tubing in sour condensate wells led to an investigation of possible causes. The presence of hydrogen sulphide suggested sulphide stress corrosion cracking. The effect of untempered martensite on the susceptibility of steel to this cracking was studied in laboratory tests. Below 30–35% martensite it is not susceptible. From 30–35 to 70–85% martensite, the permissible applied stress to avoid failure decreases with increase of this phase. Over 75–80% martensite, any applied stress seems to cause failure. When martensite begins to show continuity in the microstructure, the steel becomes susceptible.—J. F. S.

Surface Pipe Effect—Cathodic Protection of Oil Well Casing. J. P. Barrett. (*Corrosion*, 1955, **11**, Oct., 17–18). The fall towards anode potential often observed near ground level in cathodically-protected oil well casing is not accompanied by corrosion. Protection extends to the top of the buried casing.

Methods of Testing for Corrosion Fatigue. A. V. Ryabchenkov and E. L. Kazimorvskaya. (*Zavodskaya Laboratoriya*, 1955, **21**, (3), 345–349). [In Russian]. After a discussion of some corrosion-fatigue testing methods and machines used in the U.S.S.R., two series of such tests, at ordinary temperatures and at 700° C, are described. It is concluded that, to be reliable, laboratory corrosion-fatigue tests must reproduce closely the composition of the medium in which the steel is to work and the conditions of their interaction.—S. K.

Low Nickel Type 329 Offers Good Corrosion Resistance. R. A. Lula, W. G. Renshaw, and J. B. Hill. (*Iron Age*, 1955, **176**, Sept. 8, 74–76). Type 329 is a stainless steel containing 4% nickel. Its properties are described and it is suggested that in some applications it could be used in place of more critical materials. Corrosion resistance to chlorides and sulphuric and nitric acids can be good. After welding, however, it must be thoroughly annealed.—D. L. C. P.

Corrosion Control of Underground Power Cables in New York. F. E. Kulman. (*Trans. Amer. Inst. Elect. Eng.*, 1954, **73**, Part IIIA, 745–760). The factors governing the corrosion of underground power cables are discussed, and the mitigation of corrosion of this nature by protective measures, control and inspection in New York is described. In a section dealing with the installation of steel pipe conduits the protection of the pipe with a mastic coating and methods of surface inspection are described. The causes of underground steel pipe corrosion are discussed, and the use of cathodic protection is treated in detail.—L. D. H.

The Oxidation of Metals. U. R. Evans. (*Rev. Pure App. Chem.*, 1955, **5**, Mar., 1–21). A simplified analysis is presented of the kinetics of metallic oxidation for the cases (*a*) where the rate of thickening of the oxide film is controlled by the passage of material through the film; (*b*) where a boundary reaction is the rate-controlling mechanism and (*c*) where the field-transport of ions through the boundary charge films or the tunneling of electrons through them is the controlling factor. The effect of increase and decrease in the active area of oxidation is also considered. The present state of knowledge is reviewed. (64 references).—A. D. H.

Electrochemical Principles of Metallic Coatings. L. L. Shreir. (*Indust. Finishing*, 1955, **8**, May, 261–267; June, 326–333; July, 389–394, 400). The electrochemical theory of corrosion is briefly outlined with special reference to polarization and conditions existing at pores in metal coatings.

Effect of Tempering Temperature on Stress-Corrosion Cracking and Hydrogen Embrittlement of Martensitic Stainless Steels. P. Lillys and A. E. Nehrenberg. (*Trans. Amer. Soc. Metals*, 1955, **48**, Preprint No. 30). Beam type specimens of four stainless steels previously tempered at various temperatures in the range 150° C to 650° C were stressed by bending, generally well below the elastic limit, and were either exposed to 5% NaCl spray or arranged as the cathode in a cell containing 0·1N H_2SO_4 plus 3 mg As/litre as the electrolyte. The results indicate that delta ferrite minimises the tendency

for stress-corrosion cracking by narrowing the range of tempering temperatures which produce susceptibility and by interfering with crack propagation.—E. E. W.

Cathodic Protection. W. G. Waite. (*J. Jun. Inst. Eng.*, 1955, **65**, July, 293–305). The principles, applications and economics of, and the techniques employed in cathodic protection are discussed.—L. E. W.

Corrosion of Galvanised Steel Coke Hods and Buckets. J. H. Morgan. (*Corrosion Techn.*, 1955, **2**, Sept., 297–298). The author discusses briefly the results of an experimental study of the corrosion of galvanized steel in contact with coke.

Corrosion of Internal Tank Surfaces in Non-Conservator Transformers. M. Waters. (*Brit. Elect. Allied Ind. Res. Assoc. Rep.*, Q/T 130, 1951, 18 pp.).

Effect of Steam Admixtures on the Fatigue Strength of Turbine Blades. M. Werner. (*BWK*, 1955, **7**, Oct., 433–439). The theory ascribing corrosion failure of turbine blades to the action of sulphides on the nickel contained in them is challenged on the basis of experiments carried out by the author. Failure is shown to be independent of the nickel content, and determined essentially by the *p*H value of the steam condensate forming on the blades.—P. F.

Anodic Passivation of Iron and Cathodic Passivation of Magnetite. M. Pražák and V. Pražák. (*Chem. Listy*, 1955, **49**, (8), 1139–1143). [In Czech]. Both processes were studied in solutions of 1N sulphuric acid. The mechanisms are similar in both cases: a passive layer is formed which is stable under the conditions characteristic of passivation. In the anodic process it is a layer of oxide on the iron, in the cathodic process a layer of iron on magnetite. The break-down potential of the passive state corresponds to definite FeO/Fe_2O_3 and Fe/FeO equilibria in the two cases respectively. The magnitude of the corrosion current in the passive state is determined by the rate of reaction in the solid state, and is influenced by the nature of the layer.—P. F.

Study of the Constitution of Oxidation Films on Iron and Various Binary Alloys by Electron Diffraction. J. Moreau and J. Benard. (*Publ. Inst. Rech. Sid.*, Series A, 1955, May, (109), 1–26). Armco, Puron (Westinghouse) and AM (IRSID) iron, and Fe–Ni, Fe–Cr, and Ni–Cr alloys of varying compositions were oxidized, and the surface oxide films were examined by electron diffraction methods. Diffraction of reflected beams provided information concerning the surface layer, while diffraction of transmitted beams indicated the nature of underlying layers. Texture of the oxidized films is discussed.

Corrosion Inhibitors. B. Le Boucher. (*Corrosion et Anticorrosion*, 1955, **3**, July-Aug., 147–163). After a survey of the theories of cathodic and anodic polarization, the mechanisms by which passivating, anodic, cathodic, and organic inhibitors function are examined. Organic inhibitors are of particular interest owing to the difficulty in establishing a relationship between structure and effectiveness. Possible methods for inhibitor research are critically reviewed, and an example is given of the application of electrochemical methods. The effect of successive modifications in structure on the protective properties of an organic inhibitor for steel is investigated.—T. E. D.

The Oxidation of Iron–Nickel Alloys. R. T. Foley, J. V. Druck, and R. E. Fryxell. (*J. Electrochem. Soc.*, 1955, **102**, Aug., 440–445). The oxidation of an iron–42% Ni alloy was studied at 600°–900° C using gravimetric and metallographic methods. X-Ray and electron diffraction techniques were used to determine the constitution of the scale which was also analysed chemically. The oxidation rate was parabolic and the temperature variation could be expressed by the Arrhenius equation. The oxide film consisted of nickel ferrite next to the alloy and Fe_2O_3. The method of surface preparation had an influence on the rate of oxidation and on the composition of the oxide layer.—A. D. H.

A Theoretical Basis for a New Method of Investigating Corrosion Inhibition. J. G. Jewell. (*J. Electrochem. Soc.*, 1955, **102**, Apr., 198–205). An expression is derived using the Müller–Cupr model of electrochemical corrosion which can be used to assess the suitability of substances as cathodic inhibitors. The function may be determined by potential measurements when an external current is applied.—A. D. H.

An Interpretation of the Significance of the Potentials of Passive Iron. M. J. Pryor. (*J. Electrochem. Soc.*, 1955, **102**, Apr., 163–169). The application of the oxide-film theory of anodic inhibition to account for passive potentials and their variation with different solution conditions was investigated. The effect of the surface condition of the iron, the oxygen content of the solution, and the addition of chloride ions and inhibitors such as sodium phosphate, chromate, benzoate etc. were determined. Anodic inhibitors forming hydrated oxide corrosion products caused the passive potential to become less noble with increasing *p*H, but the potential became more noble in phosphate solutions. Increasing the oxygen concentration makes the steady state values of the passive potential more noble. Surface treatments and chloride additions alter the potential at high *p*H values. The effects are explained in a semiquantitative manner by the oxide film theory.

A New Design of Spray-Test Cabinet. W. Hess. (*Werkstoffe Korrosion*, 1955, **6**, July, 325–328). The author describes a new type of spray-test cabinet. Its main novelty lies in the method of producing the spray, by centrifuging instead of by an air blast. This yields a more uniform spray, consisting of aerosol particles ranging in diameter from 0·1 to 10 μ. The chamber containing the specimens is made of transparent plastic and can be heated so as to produce different internal relative humidities.—J. C. H.

Contribution to the Study of the Corrosion Resistance of a Mo and Cu containing 20/25 Cr–Ni Steel. G. Reichenberg. (*Rev. Nickel*, 1955, **21**, July-Sept., 58–64). The attempt was made to determine, for a particular steel, the corrosion resistance in strong acid media as a function of the thermal treatment of the steel and also of the concentration and temperature of the corrosive medium. Cast steel was used for the tests, and its analysis was 0·08% C, 26·3% Ni, 19·7% Cr, 5·0% Mo, 2·55% Cu, 0·83% Mn, and 1·33% S. Extensive testing was performed in sulphuric acid, but corrosion in hydrochloric, nitric, tartaric, phosphoric, and citric acids was also examined.—T. E. D.

The Protection of Structural Steel—The Protection of Steelwork in Chemical Factories. F. R. Himsworth. (*Chem. Indust.*, 1955, Dec. 10, 1618–1622). This paper describes the methods which have been found successful in the protection of chemical plant steelwork by painting, spraying, or by other means. They are generally more costly than the conventional methods but are justified by the heavy expense of frequent repainting and possible loss of production through replacement of parts. No reference is made to corrosion caused by actual spillage of corrosive liquids.—E. E. W.

The Protection of Structural Steel—Physical Examination of Paints in Relation to their Practical Performance. H. W. Talen. (*Chem. Indust.*, 1955, Dec. 3, 1564–1574). An account of the theoretical and experimental work on the mechanical properties of paint films, in which experiments using tensile tests are also discussed.—E. E. W.

The Protection of Structural Steel—Long-time Tests Carried out by the Swedish Committee on Corrosion with Painted and Galvanized Steel Plates Exposed to Air. P. Nylén and K. F. Trägårdh. (*Chem. Indust.*, 1955, Dec. 3, 1574–1587). The paper describes experiments made by the Swedish Corrosion Committee on the protection of steel against atmospheric corrosion by paint and by galvanizing. It summarizes the results and gives useful practical advice especially on priming and finishing paints.—E. E. W.

The Protection of Structural Steel—Some Results of Recent Investigations of the Corrosion Committee of the ABEM. M. Van Rysselberghe and D. Bermane. (*Chem. Indust.*, 1955, Dec. 3, 1587–1589). An account is given of tests made on 67 priming paints, having the same pigment/vehicle ratio. The main conclusions are that primers containing synthetic resins and mixtures of pigments based on zinc chromate, basic lead sulphate or, for certain purposes, powdered zinc are as good as, if not better than, red lead in linseed oil paint.

Theory of Corrosion and Passivity of Iron. W. T. Denholm. (*Australian Inst. Metals: Australasian Eng.*, 1955, Aug. 8, 46–56). The application of the pH– potential diagram to the study of corrosion of iron is discussed. Thermodynamic evidence is given to support the view that anodic passivation of iron and platinum occurs by the same mechanism, namely, the adsorption of a monolayer of oxygen on to metal atoms still in the solid lattice. With platinum this is the sole anodic process, but with iron the adsorption process occurs in competition with other mechanisms of oxide formation involving metal dissolution followed by precipitation of loosely adherent oxide films from solution. (25 references).—P. M. C.

Use of Radioactive Isotopes for Laboratory Investigations of the Corrosion Processes of Steel in Natural Waters. I. E. Apèl'tsin. (*Zavodskaya Laboratoriya*, 1955, **21**, (1), 36–38).

[In Russian]. The method of investigating steel corrosion in water described is based on the deposition on the corroded parts of the surface of radioactive calcium, added in small quantities to the water. The corrosion process is followed by the growth of the number of radioactive impulses from the immersed steel surface. The method can be used for comparing the effectiveness of various corrosion-inhibitors or the corrosion stability of various steels in the same neutral liquid. Autoradiographs of immersed steel plates show clearly the anodic and cathodic parts of the micro-cells.—S. K.

Controlling Corrosion with Cathodic Protection. H. R. Ludeker. (*Metal Progress*, 1955, **68**, Aug. 1, 86–90).

Valves for Corrosive Fluids. E. G. Holmberg. (*Corrosion*, 1955, **11**, Sept., 58–66). Methods of selecting valves for control of corrosive fluids are described. These include service trials, pilot plant tests, laboratory tests approximating to service conditions and accumulation of data on the corrosion resistance of the material under similar conditions. Small variations in composition can have a major effect on corrosion resistance. Case histories of valve failures are given and discussed.—J. F. S.

Countermeasures for Control of Internal Corrosion of a Tanker Ship. C. P. Dillon. (*Corrosion*, 1955, **11**, Sept., 45–57). The internal corrosion of wing tanks of a particular tanker is discussed in terms of cost and corrosion mechanism. Various countermeasures are discussed. The method adopted for this ship, addition of an oil-soluble inhibitor to the cargo and an inhibited salt water wash of empty tanks, is expected to reduce corrosion by 75%, and to halve the annual corrosion costs.—J. F. S.

Atmospheric Galvanic Couple Corrosion. K. G. Compton, A. Mendizza, and W. W. Bradley. (*Corrosion*, 1955, **11**, Sept., 35–44). Tests to provide fundamental information on the behaviour of galvanic couples in the atmosphere are reported. Thin sheets of the electrode materials separated by filter paper soaked in electrolyte were used for potential and corrosion current measurements. Threaded rods of cathode material with a wire of anode material wound round the threads were used for atmospheric exposure (weight loss) tests. Materials tested were classed in five groups according to their galvanic behaviour in the tests:—I, magnesium; II, aluminium, zinc, cadmium; III, iron and carbon steels, lead, tin; IV, nickel, chromium, corrosion-resisting steels; V, copper–nickel alloy, copper–zinc alloy, copper, silver, gold. Materials within a group are usually compatible when coupled together. A metal will usually suffer galvanic corrosion when coupled to a member of a group below it and exposed to the atmosphere.

Corrosion of Materials Subjected to Locomotive Smoke and Funnel Blast. T. Marshall and R. M. Sinclair. (*Corrosion*, 1955, **11**, Sept., 31–34). Numerous constructional materials and protective coatings have been examined for resistance to smoke, steam, and direct funnel blast from coal- and oil-burning locomotives. Results indicate that molybdenum-bearing austenite stainless steel and vitreous-enamelled steel are highly resistant to deterioration in these conditions.

Principles Applicable to the Oxidation and Corrosion of Metals and Alloys. W. W. Smeltzer. (*Corrosion*, 1955, **11**, Sept., 18–26). The growth and protective properties of oxide films on metals are explained in terms of kinetic phenomena. Metals are grouped according to whether their oxides have an excess or deficit of metal ions in the lattice. Theories of oxidation are considered in terms of lattice defects which may govern rate of diffusion of ions. Effects of alloying elements are discussed in terms of oxide films consisting of mixtures or solid solutions of oxides or intramolecular oxides. Aluminium is used to illustrate the theories.—J. F. S.

Stress Corrosion Cracking of Hardenable Stainless Steels. F. K. Bloom. (*Corrosion*, 1955, **11**, Aug., 39–49). Hardenable stainless steels, like other high strength steels are liable to crack under tensile stress in corrosive environments. The susceptibility is related to hardness. The most severe conditions are those promoting hydrogen embrittlement in the presence of chlorides to cause pitting. In such media, cracking under stress can occur at Rockwell hardness of C24 or even in a marine atmosphere at C40 or an industrial atmosphere at C45. Tempering at 1100° F or higher provided good resistance to cracking in the severest media. Internal quenching stresses alone can cause cracking in corrosive media but martempering, interrupted quenching, is helpful in avoiding this.—J. F. S.

The Electrochemistry of Inhibitor Action. R. B. Mears. (*Corrosion*, 1955, **11**, Aug., 50–52). An educational lecture on the electrochemistry of inhibitor action in which electrical terms are used to show the desirable properties in an inhibitor. The mechanisms for sodium chromate and sodium hexametaphosphate are discussed in detail.—J. F. S.

Design and Application of Corrosion Current Measuring Instruments. D. L. Ham. (*Corrosion*, 1955, **11**, Aug., 31–34). The main types of instrument used to measure current and potential and particularly useful for cathodic protection investigations are described and compared.—J. F. S.

The Pertechnetate Ion as an Inhibitor of the Corrosion of Iron and Steel. G. H. Cartledge. (*Corrosion*, 1955, **11**, Aug., 23–30). Theoretical consideration of inorganic inhibitors of the XO_4^{n-} type led to the examination of the pertechnetate ion TcO_4^-. It was found to inhibit corrosion of iron and carbon steels in aerated water at temperatures from 23° to 250° C. The useful chemical and nuclear properties of technetium made it possible to show that only radiochemical traces need be precipitated to obtain inhibition. The amount precipitated did not increase with time. A minimum concentration of dissolved pertechnetate was required to maintain protection. The evidence suggests a weak reversible adsorption. The perrhenate ion ReO_4^- although similar in charge and geometry was not found to have inhibitory qualities. It is tentatively suggested that inhibition arises from internal polarity sufficient to induce electrostatic polarization at the interface so increasing the activation energy of the cathodic part of the corrosion process.—J. F. S.

Effects of Chemical Composition and Heat Treatment upon the Microstructure and Corrosion Resistance of AISI Types 309 and 310. D. J. Carney and E. R. Rosenow. (*Trans. Amer. Soc. Metals*, 1955, **48**, Preprint No. 8). Two types of steel (25% Cr–12% Ni and 25% Cr–20% Ni) with varying carbon and nitrogen contents were subjected to different solution annealing treatments and cooling rates. The effects of carbon and nitrogen on intergranular corrosion resistance were noted in tests using boiling 65% nitric acid and boiling copper sulphate–sulphuric acid. Variations in the processing affected microstructures, in some cases higher carbon contents yielding improved intergranular corrosion resistance.—E. E. W.

How Zinc Coatings Slow Atmospheric Corrosion. O. B. Ellis. (*Iron Age*, 1955, **176**, Aug. 18, 79–81). The properties of zinc-coated sheets in various atmospheres are described. The results of long-term corrosion tests at selected places are referred to. New York's atmosphere was more severe than other industrial and marine locations.—D. L. C. P.

Treatment of Boiler Water. G. Bolognesi. (*Ing. Mecc.*, 1955, **4**, Jan., 5–8). [In Italian]. The author reviews a number of recently published papers dealing with water-treatment problems. Particular reference is made to corrosion and caustic embrittlement.—M. D. J. B.

The Effect of Various Alloying Elements on the Siliconizing of Steel. E. Fitzer. (*Arch. Eisenhüttenwesen*, 1955, **26**, Mar., 159–169). Silicon diffusion layers of more than 11% Si are acid resistant, but porous. The effect of aluminium, chromium, molybdenum, phosphorus, titanium, tungsten, and zirconium on the formation of the silicon diffusion layer was studied using a number of siliconizing methods which are described. Silicon diffusion layer has an increased resistance against (*a*) scaling when using chromium, aluminium, and titanium as additions and (*b*) corrosion when using chromium, molybdenum, and tantalum.—T. G.

The Attack of Manganese-Bearing Iron by Iron-Saturated Zinc Melts. H. J. Wiester and D. Horstmann. (*Arch. Eisenhüttenwesen*, 1955, **26**, Apr., 199–204). The attack of manganese-bearing iron up to 9·29% manganese by iron-saturated zinc melts was studied over a range of temperatures. The rate of attack follows a parabolic law for manganese contents up to 1·69%; the rate increases strongly for higher manganese contents but decreases for manganese contents of more than 4·09%. Iron with more than 6% manganese shows a linear rate of attack with time. The report is illustrated by a number of micrographs.—T. G.

Insulating Coatings and Their Use in the Cathodic Protection of Ferrous Alloys by Magnesium Anodes. B. Raclot. (*Métaux–Corrosion–Indust.*, 1955, **30**, June, 258–261). The advantages of combining the cathodic protection of iron and steel objects with an insulating coating, such as cement, on the metal are discussed.—B. G. B.

Some Special Features of Intercrystalline Corrosion of Austenitic Stainless Steel. A. V. Shreider. (*Zhur. Priklad. Khim.*, 1955, **28**, (6), 608–615). [In Russian]. On the basis of

results obtained in the testing of 600 melts of steel YA IT according to standard specifications GOST6032-51, it is proposed to change the lower limit of titanium content of 5(C–0·03)% to a higher one of 5·8% C and to decrease carbon content to 0·10%. Some remarks as to the reliability of standard methods of testing the tendency of steel to intercrystalline corrosion are made.—V. G.

The Corrosion of Alloy Steels and Nickel Alloys by Phosphoric Acid. J. Bünger. (*Werkstoffe Korrosion*, 1955, **6**, Aug.-Sept., 369–374). Quantitative determinations of the resistance of 12 rust-resisting steels and of 4 high-nickel alloys to corrosion by phosphoric acid under laboratory conditions are reported. The acid concentration was varied over the range from 1 to 85%, and the temperature between room temperature and the boiling point of the concentrated acid (about 160° C). The author concludes from the results that the best steel for practical use is an 18/25/2/2 Cr–Ni–Cu–Mo steel, the corrosion rate of which at all acid concentrations did not exceed 4 mils (0·004 in.) per year at temperatures up to 100° C. None of the steels resisted the strongest acids satisfactorily at higher temperatures than this but a 67/30 Ni–Mo alloy was attacked at the relatively slow rate of only 6·4 mils per year even by the boiling 85% acid.—J. C. H.

On the Mechanism of the Corrosion of Buried Iron by Soils. T. Markovic, Z. Dugi, and B. Sribar. (*Werkstoffe Korrosion*, 1955, **6**, July, 334–337). The authors report the results of further laboratory experiments on the corrosion of buried iron, the rate of which is determined by the *p*H of the soil, if excess of oxygen is present. The corrosion process is a reaction of the first order in soils that are not saturated with water but is controlled by diffusion in saturated soils.—J. C. H.

Acid Corrosion Inhibition by High Molecular Weight Nitrogen-Containing Compounds. R. A. George and N. Hackerman. (*Corrosion*, 1955, **11**, June, 19–24). The adsorption of long-chain amines, amine acetates, quaternary salts, and ethylene oxide–octadecylamine condensates on steel was determined. The rates of dissolution in acid solutions of steel so treated and of clean steel in acid solutions containing the inhibitors were studied. Adsorption from benzene solution on to steel takes place through both amine groups of dodecylenediamine. The corresponding amine salts were not so effectively adsorbed as the amines but a high-molecular-weight quaternary salt was strongly adsorbed. In this dodecyl series, the inhibitive action became less marked through the quaternary salt, diamine, monoamine, and monoamine acetate. Inhibition is attributed primarily to a diffusion barrier established by general adsorption and is increased when barrier depth, closeness of packing, and bonding forces between inhibitor and metal are increased.—J. F. S.

Control of Internal Corrosion of a Products Pipe Line System. P. L. DeVerter and A. W. Jasek. (*Corrosion*, 1955, **11**, June, 31–36). Experience of corrosion control in an 8-in. fuel pipeline is described. A water-soluble inhibitor did not give the protection desired. Oil-soluble inhibitors gave protection not only to the pipe-line but to the users' systems beyond. The inhibitor selected should be evaluated in the laboratory to determine the effect on product quality.—J. F. S.

Corrosion Monitoring for Chemical Plant. C. Edeleanu. (*Corrosion Techn.*, 1955, **2**, July, 204–208). The author considers that potential measurements can provide means of monitoring chemical plant from a corrosion point of view. The method is demonstrated for the case of sulphuric acid in a small stainless steel container.—L. E. W.

Corrosion Research Laboratories—4. The Corrosion Section of the British Iron and Steel Research Association. K. H. Gibbons. (*Corrosion Techn.*, 1955, **2**, July, 209–212). The history and organization of, and the facilities available at, the corrosion section of B.I.S.R.A. are described and various researches are outlined.—L. E. W.

ANALYSIS

Analysis of Stainless Steels by X-Ray Fluorescence. M. F. Hasler and J. Rittenhouse. (*Amer. Inst. Min. Met. Eng., Elec. Furn. Steel Conf. Proc.*, 1954, **12**, 140–148). The authors demonstrate the present role of X-ray fluorescence analysis in electric steelmaking, referring particularly to analysis of stainless steels. The development of the X-ray Quantometer is described, and the limitations and accuracy of the method are discussed.—G. F.

On the Determination of Nitrogen by the Distillation Method. B. A. Generozov. (*Zavodskaya Laboratoriya*, 1955, **21**, (3), 302–303). [In Russian]. Various methods for accelerating the distillation of ammonia during the determination of nitrogen in iron and steel have been studied. Rates of distillation under ordinary conditions, with the passage of steam and with the passage of air under reduced pressure were compared. The last gave the best results, all ammonia being removed in 3 min from artificial ammonia solutions and in 10–12 min from solutions containing precipitated hydroxides. The results of these experiments are incorporated into a procedure proposed for the determination of nitrogen in carbon or alloy steels.—S. K.

Systematic Process for the Analysis of O.H. Slags with the Use of Photocolorimetry. V. M. Bereznyak, V. A. Begma, and V. I. Zhuravskaya. (*Zavodskaya Laboratoriya*, 1955, **21**, (3), 298–301). [In Russian]. In the procedure described 0·5-g of the finely-powdered sample of O.H. slag is brought into solution in such a way that most of the components can be determined from the one weighed portion. The volume of the solution is made up to 500 ml and aliquot portions are taken for the determination of SiO_2, Al_2O_3, total iron, MnO, MgO, P_2O_5, Cr_2O_3, and TiO_2 by photocolorimetric methods, and of CaO by a volumetric method. The results obtained agree with those of gravimetric and volumetric determinations. Separate portions of the sample are taken for the determination of FeO and sulphur.—S. K.

Quantitative Spectrographic Analysis with the Aid of the Steeloscope. A. M. Borbat, M. S. Soskin, and S. G. Finkel'shtein. (*Zavodskaya Laboratoriya*, 1955, **21**, (3), 313–316). [In Russian]. Methods are described for the quantitative analysis of various ferrous and other alloys with the aid of a standard steeloscope and an A.C. arc. No photometric devices are needed, the basis of the methods being the electro-erosion of the sample. A special revolving false electrode is used for the deposition of the element being estimated.—S. K.

Methods of Investigating Standard Samples for Spectrographic Analysis. A. B. Shaevich. (*Zavodskaya Laboratoriya*, 1955, **21**, (3), 332–336). [In Russian]. Methods of determining the chemical composition of standard samples used in the spectral analysis of steels and the field of application of these samples are discussed.—S. K.

Determination of Aluminium in Plain Steel using EDTA and Dichlorodiethyl Ether. C. Elliott and J. W. Robinson. (*Anal. Chim. Acta*, 1955, **13**, Sept., 235–238). A gravimetric method has been developed which involves the extraction of iron using steam-distilled dichlorodiethyl ether instead of amyl acetate. The advantages of the former are that it is cheaper and more readily available, heavier than water, not so soluble in strongly acid solution and less of a fire hazard. The separation is completed using the disodium salt of EDTA and the aluminium is precipitated with oxine.—E. E. W.

Production Control Quantometer. (*Mech. World*, 1955, **135**, Oct., 447–448). Brief details are given of the quantometer used at the works of Steel, Peech and Tozer Ltd. (United Steel Co.) for the rapid spectrographic routine analysis of steels, slags, and sinters.—D. H.

Analytical Determination of Trace Constituents in Metal Finishing Effluents. VI. The Colorimetric Determination of Chromium in Effluents. E. J. Serfass, R. F. Muraca, and D. G. Gardner. (*Plating*, 1955, **42**, Jan., 64–68). Detailed procedures are given for the colorimetric determination of total and sexavalent chromium in the range 5–50 p.p.m. in the presence of up to 5000 p.p.m. of other cations using *s*-diphenylcarbazide. If the iron content is < 100 p.p.m. and organic matter is absent the procedure may be simplified.

Simultaneous Polarographic Determination of Cadmium and Zinc in Alkaline Cyanide Solutions. T. A. Downey. (*Plating*, 1955, **42**, Mar., 267–270).

The Applications of Polarography to the Analysis of Electroplating Solutions. R. Diaz. (*Plating*, 1955, **42**, Apr., 415–416). A brief review is made of the literature relating to the analysis of plating solutions by polarography. (21 references).—A. D. H.

Recent Developments towards the Realization of a Direct Analysis Apparatus. Macq. (*Centre Doc. Sider., Circ. Inform. Tech.*, 1955, **12**, (9), 1811–1820). An apparatus for direct analysis is described. It consists of three components: (1) An electronically-controlled spark or arc generator. (2) A 2-m spectroscope with a concave grating, which has the advantages of high luminosity, and high resolving power with absence of phantom rays. (3) An electronic set-up for registering the intensity of the rays. Recent developments in these instruments are described.—T. E. D.

Direct-Reading Spectrography with Special Reference to the Analysis of Ferrous Metals with the Quantometer. A. Argyle. (*J. West Scotland Iron Steel Inst.*, 1954–55, **62**, 27–53). A review is given of the development of spectrographic techniques in connection with metallurgical analysis, followed by a description of types of quantometer. Thereafter, operational experience with, and maintenance of one type is discussed, and the paper concludes with some general information on quantometers.—L. E. W.

New Method for the Gravimetric Determination of Tungsten. Infra-Red Absorption Spectra of Tungstates Precipitated at Different pH. T. Dupuis. (*Compt. Rend.*, 1955, **240**, Feb. 28, 978–980). The addition of a saturated aqueous solution of purpureocobaltic chloride to an aqueous alkali tungstate solution at a pH < 7 produces in the cold a pink precipitate, the composition of which varies according to the pH. Their compositions have been confirmed spectrographically. The technique may be adapted to automatic determinations with an error of $\pm$ 0·6%. Iron does not interfere with the tungstate precipitations.—G. E. D.

Potentiometric Determination of Large Amounts of Manganese. M. Malínek. (*Hutnické Listy*, 1955, **10**, (10), 612–613). [In Czech].

Electrolytic Determination of Carbon in Steels and Carbides. M. Šícha. (*Hutnické Listy*, 1955, **10**, (9), 535–542). [In Czech]. A sensitive method for carbon analysis, which is rapid and suitable for works use with carbon contents as low as 0·003 mg, is described. It is based upon the measurement of the conductivity of a barium hydroxide solution from which the barium ion is progressively precipitated by the carbon dioxide formed as a result of the combustion of the carbon in the sample to be analysed.—P. F.

A Rapid Quantitative Method for Determining Chromium, Molybdenum, Vanadium, Manganese, Nickel and Copper in Alloy Steels. M. Zimmerman. (*Mitt. Vereins Grosskesselbeisitzer*, 1940, (79/80), Dec., 111–112). Characteristic colour reactions for the above elements are given.—V. G.

High Frequency Combustion—Volumetric Determination of Carbon in Metals. E. L. Simons, J. E. Fagel, E. W. Balis, and L. P. Pepkowitz. (*Analy. Chem.*, 1955, **27**, July, 1119–1122). The variables present in the high frequency-volumetric method for the determination of carbon in metals are examined, and means of controlling or correcting them are discussed. The experimental work was done with commercially available Lindberg equipment, and the standard deviation was established. Results of analyses of standard steels are quoted.—T. E. D.

The Determination of Small Aluminium Contents in Steel. W. Werz and A. Neuberger. (*Arch. Eisenhüttenwesen*, 1955, **26**, Apr., 205–208). The authors review the commonly-used analytical methods for the estimation of small amounts of aluminium in steel and give full details of each method together with the accuracies obtained. Eriochrome-cyanine is more suitable as a reagent in the photometric aluminium estimation than aluminon.—T. G.

The Determination of Boron in Steel. H. G. Short. (*Arch. Eisenhüttenwesen*, 1955, **26**, Apr., 209–212). The author reviews the methods used for the estimation of boron in steel, e.g. volumetric, colorimetric, and spectrometric.—T. G.

The Determination of Small Quantities of Nickel in the Presence of Cobalt and Iron. M. Pontet. (*Chim. Analy.*, 1955, **37**, Oct., 338–339). A method is fully described for determining traces of nickel in iron- and cobalt-rich materials. The optical density of a chloroform solution of nickel dimethylglyoxime is measured after separation of the iron and elimination of the cobalt.—T. E. D.

Trace-Element Sensitivity: Comparison of Activation Analysis with other Methods. W. W. Meinke. (*Science*, 1955, **121**, Feb. 11, 177–184). The increasing availability of nuclear reactor facilities enables this form of analysis to be of considerable use.—B. G. B.

Quantitative Spectrographic Analysis of Refractory Clays for Fe_2O_3, TiO_2, MgO and CaO in Solutions. Yu. A. Sherstkov. (*Zavodskaya Laboratoriya*, 1955, **21**, (3), 320–324). [In Russian]. A combination of chemical and spectrographic methods has been developed for the analysis of refractory clays with a normal composition of 58% SiO_2, 32% Al_2O_3, 2% Fe_2O_3, 1·5% TiO_2, 0·5% CaO, and 0·7% MgO. One analyst can deal with 15–20 samples in eight hours by this procedure.—S. K.

Acid Cupola Slags: New Method of Rapid Analysis. V. Williams. (*Iron Steel*, 1955, **28**, Nov., 525–526). Details are given of a method for determining SiO_2, MnO, FeO, TiO_2, Al_2O_3, CaO, and MgO, in acid cupola slags. The method is sufficiently rapid for two people to analyse eight slags per day.—G. F.

On the Mercuro-Reductometric Determination of Iron in the Presence of Chlorides. V. M. Tarayan and M. G. Èkimyan. (*Zavodskaya Laboratoriya*, 1955, **21**, (3), 304–305). [In Russian]. An investigation of the effects of the presence of hydrochloric acid on the mercuro-reductometric determination of iron is described. On the basis of these experiments a procedure for the determination of iron in silicates in the presence of hydrochloric, sulphuric or nitric acids is proposed.

The Rational Sampling of Iron Ore. M. D. E. Jonckers. (*Chim. Analy.*, 1955, **37**, Nov., 359–367). The fundamental factors and theories of the constitution of a lump sample and its reduction are given, and the practical considerations of mechanical composition, influence of the number of samples, and control and selection of sampling personnel are considered. Final error in the iron content is discussed. The current method of sampling applied at Providence, Marchienne-au-Pont, Belgium, is mentioned.—T. E. D.

Recent Advances in Fluorescence Analysis Instrumentation. D. C. Miller. (*Amer. Inst. Min. Met. Eng., Elec. Furn. Steel Conf. Proc.*, 1954, **12**, 149–155). The author describes the role of the detector in fluorescence analysis, and discusses the improvements which can be expected by the use of Geiger, proportional, and scintillation counters. The advantages and applications visualized for these detectors are reviewed.—G. F.

Determination of Manganese in Iron, Steel and Ferromanganese. II. Determination of Manganese in Ferromanganese. H. Goto and S. Watanabe. (*Nippon Kinzoku Gakkai-Si*, 1953, **17**, Apr., 194–197). [In Japanese]. For the determination of Mn, after oxidation with persulphate, by ferrous salt–permanganate titration, optimum conditions were ascertained for: H_2SO_4 concentration, boiling time for persulphate oxidation, and amounts of added H_3PO_4.—K. E. J.

Where and How Spectrography Can Help You. H. E. Boyer and F. E. Fitzgerald. (*Mat. Methods*, 1955, **41**, June, 95–99). The elementary principles of spectrum analysis as applied to the estimation of steel composition are described, and the usefulness of the spectrograph for sorting, identifying, and analysing metals is discussed.—P. M. C.

Determination of Magnesium in Nodular Cast Iron by Spectrographic Analysis. B. C. Kar and M. K. Gupta. (*J. Sci. Indust. Res.*, 1955, **14B**, Nov., 570–572). A description is given of the determination by a spectrochemical method using standard metal electrodes. A comparison of the results is made with those obtained using Gillam's method of chemical analysis.—E. E. W.

Photometric Determination of Microamounts of Tellurium with Sodium Diethyldithiocarbamate and its Application to the Analysis of Iron and Steel. H. Gotô and Y. Kakita. (*Sci. Rep. Res. Inst. Tohoku Univ.*, A, 1955, **7**, Aug., 365–376). Photometric determination of tellurium was studied and an analytical procedure for its determination in iron and steel is proposed as a result.—J. G. W.

Spectrographic Determination of Trace Quantities of Boron in Steel. E. F. Runge, L. S. Brooks, and F. R. Bryan. (*Analy. Chem.*, 1955, **27**, Oct., 1543–1544). Measurement of the 2497·73 Å boron line with a Littrow spectrograph crossed with an échelle permits an accuracy of about $\pm$ 10% within the range 0·0001% to 0·0006% B. The method is described mentioning quantitative calibration based on materials prepared by diluting a high-concentration standard with electrolytic iron.—T. E. D.

Preparation of Spectrographic Standards of Low Boron Content for Determination of Boron in Iron. J. C. Shyne and E. R. Morgan. (*Analy. Chem.*, 1955, **27**, Oct., 1542–1543). The vacuum melting technique for producing samples of steel containing accurately known quantities of boron is described. Casting and rolling methods are outlined. The method is applicable to as little as 1 p.p.m. of boron.—T. E. D.

Analysis of Iron Pickle Liquor by Means of Ion Exchange. S. Fisher and R. Kunin. (*Analy. Chem.*, 1955, **27**, Oct., 1649–1650). Total cation concentration is determined by conversion to hydrogen ion by means of a sulphonic-acid-type cation exchange resin. This method, combined with a standard volumetric iron determination, permits the rapid analysis of iron-pickle liquor for iron and acid content.

Amperometric Titration of Iron with 1-Nitroso-2-Naphthol. R. F. Wilson and H. G. Loveday. (*Analy. Chem.*, 1955, **27**, Aug., 1231–1233). Optimum conditions for titration are described. The method necessitates fewer operations than usual. Of the cations studied, only lead interferes, and the method is suitable for ores or steels.—T. E. D.

Rapid Determination of Cobalt in Alloy Steels by the Tetraphenylarsonium Method. L. P. Pepkowitz and J. L. Marley. (*Analy. Chem.*, 1955, **27**, Aug., 1330–1331). A modification of Potratz's rapid colorimetric method is described for particular application to stainless steels.—T. E. D.

Detection of Stannic Ions with 7-Hydroxyphenoxazone-(2). E. Ružička. (*Chem. Listy*, 1955, **49**, (11), 1729–1730). [In Czech]. The divalent tin ion can be detected in a test tube or on filter paper. The compound also reacts with ferrous, chromous, and titanous ions, and these may first have to be removed. Ferric ions interfere and must be removed by alkalization of the solution.—P. F.

Fractional Analysis of Secondary Phases. V. I. Prosvirin. (*Zavodskaya Laboratoriya*, 1955, **21**, (1), 56–60). [In Russian]. The fractional analysis of secondary phases is discussed with special reference to carbides in steel. The analysis consists of two stages: separation of the carbide residue into fractions; the study of these fractions by chemical, X-ray, and other methods. The method proposed enables the composition of secondary phases to be determined with an estimation of the sizes of their crystals.—S. K.

A Simple Photometric Device for a Steeloscope. N. P. Derevyagin. (*Zavodskaya Laboratoriya*, 1955, **21**, (1), 116–117). [In Russian]. A simply made photometric attachment is briefly described and results obtained in the steeloscopic analysis of various types of steel are compared with those of other methods.—S. K.

The Works Laboratory in the Efforts to Produce Better Steel. E. I. Andreev. (*Zavodskaya Laboratoriya*, 1955, **21**, (1), 124–125). [In Russian]. The role of the works laboratory at the Beloretskii steelworks in increasing productivity and efficiency is outlined and current and planned research and quality-control work are mentioned.—S. K.

The Determination of Oxygen by the Aluminium Method during the Production of Alloy Steels in Electric Furnaces. S. M. Gnuchev. (*Zavodskaya Laboratoriya*, 1955, **21**, (1), 24–25). [In Russian]. Experiments are briefly described on the applicability of the aluminium method to the determination of oxygen in steels containing manganese, chromium, vanadium, and silicon in the concentrations encountered in alloy constructional steels, and also other elements less strongly combined with oxygen. It is concluded that, provided the outer layers of the sample ingot are not included in the analysis, the method can be used in both oxidizing and reducing periods of the production of alloy steels.—S. K.

Separation of Vanadium from Titanium and Iron with the Aid of a Cation-Exchanger. L. M. Orlova. (*Zavodskaya Laboratoriya*, 1955, **21**, (1), 29–30). [In Russian]. It has been shown that vanadium can be separated from titanium by cation-exchange if the reduction of the former is prevented by hydrogen peroxide in the solution.—S. K.

Effect of Temperature on Photometric Determination of Phosphorus in Steel. H. C. Baghurst and V. J. Norman. (*Analy. Chem.*, 1955, **27**, July, 1070–1073). The molybdovanado-phosphoric complex as applied to the photometric determination of phosphorus in steel is discussed. Details are given of a method by which the sensitivity of the complex to temperature is reduced by the addition of sulphate. Analyses of various standard samples of steel are given.

Determination of Oxygen in Metals without High Vacuum by Capillary Trap Method. W. G. Smiley. (*Analy. Chem.*, 1955, **27**, July, 1098–1102). The sample is dropped into molten platinum in a graphite crucible and any oxygen in the sample reacts to form CO which is swept out by a stream of argon at atmospheric pressure. A modified form of Shütze reagent oxidizes the CO to CO_2 which is condensed in a capillary trap and is measured by a capillary manometer. A determination takes 12 min. Results for samples of iron and steel are included.—T. E. D.

The Use of Statistics for the Evaluation of the Work of Chemical Control Laboratories in Iron Foundries. R. Krzeszkowski. (*Przeglad Odlewnictwa*, 1955, **5**, (6), 171–174). [In Polish]. The use of statistics to check analytical results obtained in a foundry's control laboratories is discussed and illustrated by some examples.—V. G.

Present State of Development of Spectro-Analysis, particularly for Nondestructive Testing. H. Moritz. (*Technik*, 1955, **10**, Sept., 547–552). This is a general survey of modern spectroanalytical techniques, with reference made to its use in the Soviet Union and in Hungary.—J. G. W.

A Colorimetric Method for the Determination of Copper in Alloyed Steels with 2 : 2′-Diquinolyl. W. T. Elwell. (*Analyst*, 1955, **80**, July, 508–514). An oxidized solution of the sample is reduced with H_2SO_3, adjusted to pH 5 to 6, and extracted with 2 : 2′-diquinolyl in amyl alcohol in the presence of citric acid. The violet colour, proportional to the amount of copper present, is stable and can be suitably measured. The method has been successfully applied to carbon and highly-alloyed steels, ferro-alloys, and pure cobalt and nickel containing 0·001 to 1% Cu. It is not recommended as a precise method for more than 0·25% Cu.—T. E. D.

The Bomb Method for the Determination of Sulphur and Chlorine in Coal. Z. K. A. Moszynski. (*J. Appl. Chem.*, 1955, **5**, Sept., 467–470). Strambi's recent modification of the bomb-combustion method for determining sulphur in coal has been further improved in both accuracy and time taken for the determination. It has also been applied to the determination of chlorine and compares favourably with the B.C.R.A. Rapid Eschka Method.—E. E. W.

Rapid Exact Micro-Analysis of Gases. H. Feichtinger. (*Arch. Eisenhüttenwesen*, 1955, **26**, Mar., 127–130). An apparatus for the micro-analysis of gases consisting of CO_2, CO, $H_2 + N_2$, remainder (using gas volumes of 0·1–2 cm^3) is described. To an exactly determined volume of the gas to be analysed oxygen is added, the mixture ignited, and the combustion gases pressed through the absorption cells. An analysis takes about 10–15 min. The accuracy obtained is high.—T. G.

Determination of Carbon Dioxide in Coal. R. K. S. Mehta and J. W. Whitaker. (*J. Sci. Indust. Res.*, 1955, **14C**, Mar., 110–115).

Spectrographic Determination of Magnesia in Limestone. L. V. Drutskaya and I. L. Reznikov. (*Zavodskaya Laboratoriya*, 1955, **21**, (3), 324–327). [In Russian]. A spectrographic method is described for determining magnesia in metallurgical limestone. 0·5–5% MgO can be dealt with.—S. K.

Experiences with a New Method for Determining the Basicity of Open-Hearth Slag. G. Schermer and K. Schermer. (*Jernkontorets Ann.*, 1955, **139**, (8), 524–530). [In Danish]. A modification of the Smith–Monaghan–Hay method is described which enables basicity to be determined within 8 min. A small piece of the slag sample is pulverized to screen size DIN 50, granular iron being removed with a magnet. 0·2 g is placed in a 150-ml beaker, and mixed for 4 min with 100 ml boiling distilled water. A Philips GM 4221 electrode at 75–85° C is inserted and conductivity of the solution is measured with a Philips bridge. The specific resistance is then calculated with the aid of the electrode constants, the slag basicity being given by a previously established curve showing basicity as a function of specific resistance. Results are given for two months' operation with the method.—G. G. K.

INDUSTRIAL USES AND APPLICATIONS

Production and Fabrication of Heat Resistant Alloys from the Producers' Viewpoint. C. T. Evans. ('*Utilization of Heat Resistant Alloys*': *Amer. Soc. Met., Symposium*, Mar. 11–12, 1954, 148–183). The paper briefly reviews the existing practices, problems, and accomplishments of the engineering industry in the production and fabrication of semi-finished wrought heat resistant alloys for jet engine and industrial gas turbine use. The melting of the alloys by electric arc and induction furnaces is discussed together with the Kellogg and Closed Circuit melting processes.—D. H.

Thermal Bimetal Strips. W. Rienäcker. (*Schweiz. Arch. Wiss. Techn.*, 1955, **21**, Sept., 289–295). The choice of metals and the calculation of the strip curvature at different temperatures is given. The principal metals used for bimetal strips are alloys of nickel and steel.—J. R. P.

Some Fundamentals of Automotive Metallurgy. R. H. Keller. (*J. Inst. Auto. Aeronaut. Eng.*, 1955, **15**, July, 98–104). A short account of some metallurgical principles which may be encountered by an automobile engineer is presented.

Saw-Blade Alternatives. (*Usine Nouvelle*, 1955, **11**, Nov. 10, 67–69; Nov. 17, 63–65). Blade characteristics, composition

of steel used for ordinary or high-speed blades, manufacture, and blade testing are described. Advice is given on the choice and use of blades for hand saws and for ordinary and high-speed machine saws. Reasons for unsatisfactory sawing and failure of saw blades are summarized.—T. E. D.

Design Specifications for Stainless Steel, Type 301. E. W. Hammer, Jun., and R. E. Petersen. (*Reg. Tech. Meet. Amer. Iron Steel Inst.*, 1954, 49–69). The authors discuss progress made in the preparation of a design specification for the structural use of Type 301 stainless steel (16–18% Cr, 6–8% Ni). A tentative specification is outlined, and the experimental work so far carried out in verification is summarized.

Ferrous Materials in Marine Engineering. S. F. Dorey. (*N.E. Coast Inst. Eng. Ship.*, Advance Copy, 1955, Oct. 28, 27–56). The ferrous materials in particular alloy steels and high duty cast irons, their fabrication and treatment for marine machinery are discussed.—U. E.

Current Trends and Developments in the Use of Creep-Resisting Steels in Steam Power Plant. M. G. Gemmill. (*J. West Scotland Iron Steel Inst.*, 1954–55, **62**, 154–187). Confining himself to six types of steel at present in use either in superheaters or steam piping, the author considers the influence of steelmaking methods, heat treatment and fabrication. Design stresses and laboratory data are discussed, and future trends assessed. (9 references).—L. E. W.

Influence of Steel-Quality on the Testing and Durability of Articulated Boring Rods. J. Klarding. (*Rev. Ind. Min.*, 1955, **36**, Feb. 1, 278–285). The use of heat treated special steels is advocated for articulated boring-rods. Their higher costs are more than offset by savings in maintenance and repair as well as increased life. The physical properties of normal and treated steels are compared in detail.—G. E. D.

Towards Higher Quality Razor Blades. V. Sekanina. (*Hutnické Listy*, 1955, **10**, (11), 665–673). [In Czech]. Production methods and composition of blades in various countries are discussed and certain shortcomings of blades are considered. Possible improvements in production methods in Czechoslovakia are outlined.—P. F.

The Selection and Treatment of High Speed Steels. W. Sorby. (*Alloy Metals Review*, 1955, **8**, Mar., 2–9). Main properties of high speed steels and alloying elements and treatment used to obtain these properties are discussed. The main types of these steels and their uses are described.—V. G.

Developments in Low-Alloy Steels for Welded Structures. C. L. M. Cottrell. (*Alloy Metals Review*, 1955, **8**, June, 2–6). Factors involved in the development of low-alloy steels of higher strength and weldability characteristics than mild steel, are discussed. A range of such steels is given.—V. G.

Wrought Steel Wheels. (*Amer. Iron Steel Inst., Steel Prod. Man.*, 1955, Feb., 1–61). Sections on (I) Manufacturing Practices, (II) Wheel Technology, (III) Wheel Specification (reprinted by permission of Association of American Railroads and American Society for Testing Materials), and (IV) Design Data and Tables taken from the AAR Manual of Standard and Recommended Practice are included. (27 illustrations).

Railway Track Materials. (*Amer. Iron Steel Inst., Steel Prod. Man.*, 1955, Apr., 1–93). (I) Rails, (I) Joint Bars, (III) Tie Plates, (IV) Track Spikes, and (V) Track Bolts and Nuts are considered. There is also a section on the limitations of inspection, testing, and certification.—E. C. S.

Tool Steels. (*Amer. Iron Steel Inst., Steel Prod. Man.*, 1955, Apr., 1–72). Sections on (I) Manufacturing Practices, (I) Identification and Type Classification, (III) Selection of Tool Steels, and (IV) Tolerances for Dimensions and Allowances for Machining and Decarburization are included. In Section V Macroetch Inspection Guides, photographs intended to illustrate (*a*) the maximum degree of centre porosity considered allowable for the general application of straight carbon and low alloy tool steels are given on pp. 58–63 and (*b*) the maximum degree of segregation considered allowable for the general application of high alloy tool steels on pp. 65–68.

Engineering Practice for Selecting Materials and Proportioning Components Operating at High Temperatures in the Steam Power Industry. H. A. Wagner and J. A. Blecki. ('*Utilization of Heat Resistant Alloys*': *Amer. Soc. Met., Symposium*, Mar. 11–12, 1954, 106–121). Some of the more important factors which influence selection of materials for high temperature–high pressure steam service are discussed and the factors to be considered in component design for power plants are indicated.—D. H.

The Manufacture of Landing Gear from Ni–Cr–Mo Steel of High Strength. A. Daubert. (*Métaux–Corrosion–Indust.*, 1955, **30**, Oct., 397–408). The arduous conditions of service of aircraft landing gear are explained and the properties and heat treatment of a Ni–Cr–Mo steel which has proved satisfactory are described.—B. G. B.

Construction and Maintenance of Chemical Apparatus in 18/8 Stainless Steel. M. L. Guitton. (*Génie Chim.*, 1955, **74**, Sept., 75–79). The basic problems which are attached to the construction of stainless steel chemical equipment, in particular corrosion, are discussed.—B. G. B.

The Development of Metals in the Aircraft Industry. L. K. Brooks. (*Australian Inst. Metals*: *Australasian Eng.*, 1955, Apr. 7, 51–58). The development of engines and airframes from Wright's Flyer of 1903 to the present time is discussed, with special emphasis on the part played by metals. The applications of low-carbon weldable steels for braced structure fuselages, alloy steels for engine components, and various stainless qualities for exhaust manifolds are described.

Cold Reduced, Low Carbon, Sheet Steel. N. G. Fraser and J. M. Butler. (*Australian Inst. Metals*: *Australasian Eng.*, 1955, June 7, 41–47). The various grades of cold reduced low-carbon sheet steel (killed, semi-killed, and rimmed) are discussed with reference to their chemistry, methods of production by continuous rolling, and forming, and physical properties. The problems associated with ageing are reviewed. (3 references).—P. M. C.

Pick Steels for Pneumatic Picks. C. Hutchinson. (*J. Junior Inst. Eng.*, 1955, **65**, Sept., 349–360). The design and conditions of service of these picks for use in coal mining are described. Straight carbon steels are usually employed with a carbon content of 0·75%. Silicon, tungsten, and nickel alloy steels are the three best types of alloy steels and tungsten steel is usually preferred.—B. G. B.

When to Use an 18–8 Steel with 0·03% C, with 0·05% C and a Titanium Stabilized Steel. G. Lilljekvist and S. Hansen. (*Acciaio Inossid.*, 1955, **22**, July-Aug., 121–131). [In Italian]. This paper discusses the influence of carbon content on the properties and applications of austenitic 18/8 steels as well as the actions of stabilizing elements. Researches carried out at The Avesta Steelworks in Sweden are described. The authors suggest that in most cases where 18/8 stainless steels are used in chemical works, these could well be of 0·05% carbon (maximum) content for thicknesses up to 20 mm for welded vessels not subjected to heat treatment. For greater thicknesses steel with a maximum carbon content of 0·03% should be used.—M. D. J. B.

Modern High Temperature Materials. A. Erra. (*Ing. Mecc.*, 1955, **4**, Jan., 33–41). [In Italian]. This article deals with some modern high-temperature materials classified in three groups: super-alloys, ceramic materials, and cermets. The most widely used types in each group are described. Their chemical formulae are given together with their physical and mechanical properties at high temperatures. These special materials are then compared with the most commonly employed types of high-temperature steels, thereby underlining their advantages. (13 references).—M. D. J. B.

Guidance for the Constructional Engineer on the Choice of Cast Metals. (*Usine Nouvelle*, 1955, **11**, Sept. 8, 60–63). The properties of a range of iron alloys and steels which are used in castings are outlined. The particular applications of each type are given. Tensile strength, elastic limit, elongation, modulus of elasticity, Brinell hardness, density and fatigue limit are tabulated.—T. E. D.

Construction Materials for Liquid Sodium Systems. E. G. Brush. (*Corrosion*, 1955, **11**, July, 27–31). The use of sodium as a heat-transfer agent in nuclear power plants has raised problems with regard to constructional materials. These may be subject to mass transport effects, preferential solution of alloying constituents, and diffusion welding of surfaces. Traces of impurities lead to damaging oxidation and accentuated preferential solution phenomena, particularly decarburization and intergranular attack. Static and dynamic laboratory tests and pilot plant experience indicate a wide range of suitable materials including austenitic stainless steels, chromium steels containing over 12% Cr, the highly-alloyed 'super' alloy steels, and some hard facing alloys.—J. F. S.

Cold Rolled Carbon Steel Strip. (*Amer. Iron Steel Inst., Steel Prod. Man.*, 1955, Feb., 1–27). The article is divided into four parts covering: (I) Metallurgical Aspects; (II) Manufacturing Practices; (III) Quality Descriptions; and (IV) Chemical Requirements.—E. C. S.

HISTORICAL

Fifty Years' Progress in The Understanding of Metals. N. P. Allen. (*J. B'ham. Met. Soc.*, 1954, Golden Jubilee Issue, 89–109). A short review is given of the state of knowledge in metallography and atom physics in 1903, followed by the development of the modern conception of the atom. An account is then presented of the growth of knowledge during the past fifty years from the study of phase diagrams, the use of modern physical techniques such as X-ray diffraction and electron microscopy, studies of the mechanics of transformations, plastic deformation, recrystallization; and the development of the theory of dislocations.—P. M. C.

Evolution of Cast Iron Making in Europe and its Relationship with the Walloon Method of Refining. J. R. Maréchal. (*Techn. Civil.*, 1955, **4**, (4), 129–143). The history of iron-making is traced from its origins in the Eastern Alps. Refining of cast iron was first carried out in the Principality of Liége in the 16th century, and later in Germany and Sweden. The method is discussed. The history of the cementation process is also followed.—T. E. D.

Studies of Primitive Metallurgical Methods: The Primitive Iron Metallurgy of Madagascar. B. Gille. (*Techn. Civil.*, 1955, **4**, (4), 144–147). The Madagascar iron industry originated in the 16th century. A description is given of the primitive methods of ore treatment, smelting, and refining used in a native village of 200 to 300 inhabitants which depends on iron making for its livelihood.—T. E. D.

Thirteenth Century Smelting Residues from Kirkstall Abbey. R. Haynes. (*J. Iron Steel Inst.*, 1956, **183**, Aug., 359–361). [This issue].

Ancient Forging Hammers in Carinthia. K. Dinklage. (*Radex Rundschau*, 1955, July, 481–493). [In German]. An historical and technical survey is made of the development of hammer mills since their introduction from Italy in the 14th century. Details are given of various forging techniques up to the replacement of hammers by rolling mills in the 19th century. (51 references).—E. C.

The Production of Iron. R. Durrer. (*Roll'schen Eisenwerke Werkzeit.*, 1955, **26**, Sept., 107–110). The history of the production of iron is briefly discussed.—U. E.

Fifty Years of Progress in The Ferrous Industries. J. W. Jenkin. (*J. B'ham. Met. Soc.*, 1954, Golden Jubilee Issue, 81–88). The author presents a general review of the highlights of scientific and technological progress relating to the iron and steel industry, since the year 1903. Metallography, iron and steel production, heat treatment, testing, specifications, and welding are dealt with, and reference is made to some of the now historic lectures delivered to the Birmingham Metallurgical Society almost fifty years ago.—P. M. C.

Georgius Agricola. In Memory of the Great Scholar on the 400th Anniversary of his Death. G. J. M. Ertle. (*Glückauf*, 1955, **91**, Nov. 19, 1296–1307). An account is given of the life and achievements of Georgius Agricola. (39 references).

Presidential Address. H. O'Neill. (*Swansea Met. Soc., Advance Copy*, 1954, Oct. 16). A short account of the metallurgical history of South Wales is presented.—B. G. B.

Abraham Darby. E. N. Simons. (*Metallurgia*, 1955, **52**, Sept., 112–114). An historical account is given of the activities of Abraham Darby who used coke for smelting iron ore in the early 18th century at Coalbrookdale.—B. G. B.

Today's Primitives. W. L. Speight. (*Brit. Steelmaker*, 1955, **21**, Aug., 248–250). The author discusses the resource and ability of the native Barotse ironworkers of Southern Rhodesia.—G. F.

ECONOMICS AND STATISTICS

The Organisation of an Iron and Steel Industry in the Tébessa Region. (*Usine Nouvelle*, 1955, **11**, Nov. 10, 27–30). Reasons for the industrial development of the Tébessa region (Tunisia/Algeria) are discussed, with details of the resources available. The industrialization program is outlined, with details of proposed plant capacities.—T. E. D.

The European Coal and Steel Community. D. J. Ezra. (*Colliery Guardian*, 1955, **191**, Oct. 6, 413–416). The exact way in which the Treaty affects the six Community countries is described, and the powers and duties of the High Authority are considered in detail. Britain's position with respect to the Community is explained.—T. E. D.

Quantitative Comparison of the Steels of the Six E.C.S.C. Countries. L. Brandolin. (*Ing. Mecc.*, 1955, **4**, Apr., 13–16). [In Italian]. Tables are drawn up which give a quantitative comparison of the standard types of steel produced by the six E.C.S.C. countries. Pending standardization of iron and steel products in the European Community, these tables, which give grades of steel and their mechanical properties, will greatly facilitate the choice and ordering of steels in E.C.S.C. countries.—M. D. J. B.

The Steel Industry in Southern Rhodesia. A. G. Thomson. (*Iron Steel*, 1955, **28**, Oct., 475). A brief account is given of the development of Southern Rhodesia's iron and steel industry and of the expansion proposed by the Rhodesian Iron and Steel Commission.—G. F.

Expansion of World Tin Plate Potential. W. E. Hoare. (*Times Rev. Indust.*, 1955, **9**, Aug., 26–27). A short review of the activities and future developments of the major tin-plate mills in the world is presented.—B. G. B.

Steel Production in E. Germany: Post-War Expansion. E. P. Young. (*Iron Coal Trades Rev.*, 1955, **171**, July 8, 99–101). The author briefly reviews the iron and steel industry of E. Germany, indicating the coal and ore supplies and steel-making capacity, and gives details of the rapid post-war expansion.—G. F.

MISCELLANEOUS

Metallurgy in Mass Production. L. A. Danse. (*Metal Progress*, 1955, **68**, Sept., 88–92). A number of examples of the solving of production problems by metallurgical investigations are reported.—B. G. B.

Biotechnology—a Neglected Productivity Factor. C. Sebardt. (*Jernkontorets Ann.*, 1955, **139**, (10), 805–816). [In Swedish]. A general survey is made of the importance attaching to a detailed study of workers' positions and movements when undertaking routine tasks in steelworks. Examples are given of incorrect design of equipment.—G. G. K.

Workers' Positions and Movements from the Physiological Viewpoint. P. O. Åstrand. (*Jernkontorets Ann.*, 1955, **139**, (10), 817–828). [In Swedish]. Pointing out that the human locomotive organs often have to adapt themselves to the machine, instead of conversely, the author discusses lung, heart, and muscle functions and relates them to ideal working positions. Typically incorrect attitudes are illustrated.

The Transition Metals. W. Hume-Rothery. (*Met. Ital.*, 1955, **47**, July, 299–304). [In Italian]. The author discusses the fundamental problem of transition metals, namely the nature of cohesion in the elements of the group IIIA–VIIIC. A brief review is given of the physical properties which can help to clarify this subject about which little is known. The transition metals specifically considered are Rb, Sr, Yt, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Ag.—M. D. J. B.

New Heat Resistant Adhesives for Metal Bonding. G. Epstein. (*Mat. Methods*, 1955, **41**, Jan., 107–110). The applications and bonding properties of two adhesives, suitable for structural uses in aircraft, automotive, and electronic parts at temperatures as high as 600° F are described. The basic materials are phenolic resins with alkaline catalysts, and the excellent bonding characteristics are attributed to a two-stage curing procedure at 180° F, and then at 275° F under pressure. The adhesives were developed by North American Aviation Inc.—P. M. C.

Research Institutes for Ferrous Metallurgy in the German Democratic Republic. I. P. Bardin. (*Zavodskaya Laboratoriya*, 1955, **21**, (3), 261–268). [In Russian]. This is an illustrated review of research on iron and steel being carried out at various establishments in East Germany.—S. K.

Current Conceptions on Air Pollution. W. C. L. Hemeon. (*Reg. Tech. Meet. Amer. Iron Steel Inst.*, 1954, 71–97). The author discusses some of the basic conceptions which underlie current American research on air pollution. The classification of smoke and dust particles is considered, and the development of instruments to facilitate effective survey procedures is described.—G. F.

The Steel Industry and the Institute. M. D. Howell. (*Reg. Tech. Meet. Amer. Iron Steel Inst.*, 1954, 99–108; 273–283). The activities and accomplishments of the American Iron and Steel Institute are discussed, and its relationship to the American steel industry is outlined.—G. F.

Fundamental Research in Water Pollution Abatement at Mellon Institute. R. D. Hoak. (*Reg. Tech. Meet. Amer. Iron Steel Inst.*, 1954, 127–142). An account is given of the Mellon Institute's investigation of the steel industry's waste water

problems. Particular attention is given to the study of methods of processing or disposing of spent pickle liquor.

Basic Research and Tomorrow's Technology. L. A. DuBridge. (*Reg. Tech. Meet. Amer. Iron Steel Inst.*, 1954, 285–295). The author discusses the growth of basic science through the years and illustrates the attendant advances in technology.—G. F.

A Practical Approach to Air Control. J. H. Smith. (*Reg. Tech. Meet. Amer. Iron Steel Inst.*, 1954, 307–313). The author discusses the work of the Air Control and Research Dept. of Kaiser Steel Corporation, Fontana, California. The programme is divided into agricultural, engineering, and chemical sections, each of which is described.—G. F.

Technical Documentation in the Field of Stainless Steels and its Classification. C. M. Lerici. (*Acciaio Inossid.*, 1955, **22**, Jan.-Feb., 5–18). [In Italian]. The author gives a detailed description of the Universal Decimal Classification and shows how the classification is used to describe every aspect, metallurgical and technological, of all types of stainless steels.

Presidential Address. W. Regan. (*Proc. Staff. Iron Steel Inst.*, 1946–53, **61**, 52–60). Education and training in the Iron and Steel Industry are discussed.—B. G. B.

Application of a Statistical Method to the Testing of Armour Plate. A. N. Benson. (*Institut de Statistique de l'Université de Paris: Journée de la Sidérurgie*, 1954, June 22, 19–20). The sequential method of analysis is applied.—T. E. D.

Co-Operative Research. Survey of the Activities of the Research Associations. (*Metallurgia*, 1955, **52**, Oct.).

BOOK NOTICES

American Institute of Physics. "*Temperature. Its Measurement and Control in Science and Industry.*" Volume II. Edited by H. C. Wolfe. La. 8vo, pp. x + 467. Illustrated. New York, 1955: Reinhold Publishing Corp.; London: Chapman and Hall, Ltd. (Price 96*s.*).

The papers in this volume were originally presented at a symposium on temperature held in Washington in 1954, and are now issued as a second volume of the work of the same title which appeared in 1941. In this case, the title is somewhat misleading, as there is only one paper, "*Temperature Measurement in Engineering*," by H. J. Hogg (pp. 287–325), which deals with temperature measurement in industry; this is descriptive of all methods of pyrometry from thermometers to colour-indicating paints and is well illustrated with manufacturers' photographs. It is pleasing to note that Schofield and Grace are given their proper credit for the invention of the quick immersion thermocouple. The rest of the volume is of a high theoretical level, dealing with, for example, the concept of temperature itself, gas thermometry, the international temperature scale, thermometry below 1° K, astrophysical temperatures, and temperatures in atomic explosions; most of the articles carry long and comprehensive lists of references, and the presentation of the numerous diagrams, graphs, and mathematical expressions is excellent.—J. P. S.

Baker, H. W. Edited by. "*Modern Workshop Technology.*" Part I—"*Materials and Processes.*" Second Edition Revised and Enlarged. Med. 8vo, pp. viii + 511. Illustrated. London, 1956: Cleaver-Hume Press Ltd. (Price 35*s.*).

This work, first published in 1948, has been revised, by the extension of existing material and the introduction of entirely new chapters in an attempt to bring it up-to-date.

Generally, it may be stated that the various authors have succeeded in their efforts to do this, although there are several instances where they have not done so. To cite one example only, it is surely very much out-of-date to quote an obsolete specification for steel castings, viz. B.S. 592: 1940 (pp. 64 and 65). This specification was revised and published in 1950, since when many other steel castings specifications have been issued by B.S.I., only one of which, (B.S. 1398: 1947) is mentioned in the present work.

High-speed and alloy die-steels receive mention but that is about all.

The reviewer must take objection to the captions to the illustrations on p. 36. To describe such structures as a "eutectic of pearlite and cementite" is incorrect and misleading.

Objection must be raised, too, against the fallacy that the cold-working of austenitic manganese steel converts its structure into martensite. This view, which is undoubtedly widespread, has been entirely dissipated as the result of X-ray crystallographic analysis.

Generally, the non-ferrous section has been brought more up-to-date than its ferrous counterpart, but it is surprising that no mention is made of the properties of titanium.

The three additional chapters deal adequately with shell moulding and investment casting, the production of high-tensile steel wire and of bright steel bars.

Most of the distinguished team of authors gathered together by Professor Baker have had both teaching and industrial experience. The result has been the production of a sound and authoritative treatise which can be heartily recommended to students reading for B.Sc.(Eng.) degree or A.M.I.Mech.E. examinations. It is well-illustrated by photographs and line diagrams and the price is very modest when one considers the wealth of information it contains.

Edwin Gregory.

Hadfields, Ltd. "*Manganese Steel.*" 8vo, pp. x + 128. Illustrated. Edinburgh and London, 1956: Oliver and Boyd. (Price 18*s.*).

This excellent book might almost be called a manganese steel encyclopedia; it is well written, the tables are well set out and the diagrams and photographs are clear and well chosen.

It commences with a short historical review and of course refers to the pioneer work on manganese steels of the late Sir Robert Hadfield. What it does not mention is that such was his enthusiasm for research that when a young man he had a small crucible furnace installed in his father's house in Sheffield, and during the reviewer's childhood that crucible furnace was still intact and could indeed have been made ready for melting steel within a few hours.

The second short section gives the general characteristics of a steel containing approximately 1·2% carbon and 12·5% manganese, and is followed by a section dealing with its manufacture and processing. The mechanical properties are adequately dealt with in the next section, and then follow sections dealing with heat-treatment, transformational characteristics and metallography, work-hardening, abrasion and wear resistance, and the influence of temperature on properties. The ninth section, a fairly long one, describes the effect of modifications in composition, and is followed by a short section dealing with non-magnetic steels, which contain approximately 8% manganese, 4% chromium, and 8% nickel.

Sections 11, 12, and 13 are of particular interest to engineers who fabricate manganese steel, and cover machining, welding, hard-surfacing, brazing, and oxygen cutting. The book concludes with a number of typical microstructures and an adequate bibliography of more than 100 references. This review cannot better end than with a quotation from Mr. Colbeck's foreword, viz.: "This book will fill a long-felt want and there is no doubt that it will prove an essential work of reference for engineers and metallurgists and also a most useful book for the student. It is right that this introduction should finish with an expression of sincere thanks to the many anonymous members of the staff of Hadfields who have made this book possible."—J. Ferdinand Kayser.

Low, David Allan. "*A Pocket-Book for Mechanical Engineers.*" New [sixth] edition, edited by Bevis Brunel Low. Sma. 8vo, pp. xii + 778. Illustrated. London, New York, Toronto, 1956: Longmans, Green and Co. (Price 21*s.*).

It is certainly good to see a new edition of this valuable and well-known pocket-book, which has been available in five previous editions for nearly sixty years. The principal changes in the new edition are in the sections on engineering metals, wood, unified screw threads, bolt-heads and nuts, pipes and pipe joints, ropes, chains, chain slings and hooks, and sandblasting.

The section on ferrous and non-ferrous metals represents in nearly forty pages as concise and useful an account as is possible. It is expressed in very clear and straightforward language, and provides the sort of basic information, on both established and new materials, which is wanted by the engineer consulting such a book. One point noted here, however, is the surprising statement (p. 364) that the effect of *silicon* on the electrical conductivity of copper is not so serious as that of most other additions; the one example then quoted of a strengthened copper with good conductivity is that with up to 0·2% silicon. Nevertheless, this is only a small blemish detected in an otherwise sound account.

This book needs really no recommendation; all that is necessary is to state that in the new edition its usefulness and reliability are maintained.—A. R. BAILEY.

PHILLIPS, ARIS. "*Introduction to Plasticity.*" 8vo, pp. ix + 230. Illustrated. New York, 1956: The Ronald Press Co. (Price $7.00).

The study of the theory of plasticity of metals and its practical application has advanced rapidly in the last ten to fifteen years. Steel frame buildings are being regularly designed to allow for plastic deformations to occur, the work of Professor J. F. Baker in this country having been particularly useful in this respect. On the other hand, knowledge of the deformation occurring in metal-working processes has been both extended and applied to many industrial processes.

While much has been published, on the many aspects of plasticity, as papers to the learned societies and journals, there are still relatively few textbooks available, and the present volume recommends itself from this consideration alone.

It is necessary, however, to recognize the specialized nature of Phillips' book; it is written particularly for the civil engineer, as the greater part of it is confined to plastic design of structures. The chapters dealing with general plasticity are not entirely satisfactory, the treatment being brief and essentially theoretical in approach. Two chapters on combined-stress problems are mainly confined to conditions for collapse, and again relate principally to structures. The theory of the slip-line field, and steady state and quasi-steady state problems are meagrely dealt with. For the work on axi-symmetrical systems the reader has to turn to several points in these later chapters and no experimental assessment is attempted for this or any other topic. It may be that Phillips is addressing his book to civil engineers only; if this is so, the reviewer begs the author's pardon, but would point out that the title is misleading in that case.

Despite these criticisms, the book is to be welcomed with this more limited function.—HUGH FORD.

VEREIN DEUTSCHE EISENHÜTTENLEUTE. "*Handbuch für das Eisenhüttenlaboratorium.*" Band 3. "*Probenahme.*" Gemeinsam herausgegeben vom Chemikerausschuss des Vereins Deutscher Eisenhüttenleute and the Chemikerausschus der Gesellschaft Deutscher Metallhütten- und Bergleute e.V. La. 8vo, pp. viii + 452. Illustrated. Düsseldorf, 1956: Verlag Stahleisen m.b.H.; Berlin, Göttingen, Heidelberg: Springer-Verlag. (Price DM. 45.–; members of the V.D.E. DM. 36.–).

Very seldom is a book devoted entirely to sampling available and this one, which is the collaborative work of some sixty experts from all interested sections of the German industry, contains a large amount of relevant and informative detail.

The subject matter is split broadly speaking into two parts, the first one dealing with sampling procedures and the second with their application to specific materials. After the preliminaries of weight, volume, and grain size, the apparatus and methods of taking samples are described together with full details of machines for dealing with the samples, from hammer mills and pulverizers to shears and drilling machines. Also included here is an interesting little section on specimen layouts of sampling rooms.

The sampling of deposits, whether they be ore or coal, is naturally given a very full treatment with methods, systems, and evaluation, as also is the next stage of sampling from containers such as ships, wagons, and boxes. Metals and alloys from initial sampling to final preparation, packaging, and storage is followed by a short account of the determination of moisture. The use of the spectrograph in the analytical field is stressed, but in relation to its importance a few pages on statistics would seem out of proportion although enough information is given to understand the part that statistics do play in assessing correct sampling procedure.

The second and largest part applies the procedures to materials from aluminium to zirconium, including the allied products and raw materials. For example, the chapter on iron includes ore, pig iron, and steel, down to sampling for the determination of hydrogen in liquid steel. The final chapters include details for solid, gaseous, and liquid fuels, refractory materials, slags, flue gas, and water.

Detailed study of this admirable and well presented book reveals very clearly how necessary it is to the chemist that correct sampling procedures must be used to provide him with his sample for analysis, and it is sufficient to say that by applying the appropriate procedure given here one would obtain a reliable sample.—L. E. GARDNER.

NEW PUBLICATIONS

AMERICAN IRON AND STEEL INSTITUTE. "*Flat Rolled Electrical Steel.*" A revision of former Section 26 of the Steel Products Manual. La. 4to, pp. 86. Illustrated. New York, 1956: The Institute.

AMERICAN SOCIETY FOR TESTING MATERIALS. "*Symposium on Metallic Materials for Service at Temperatures above 1600° F.*" Presented at the Fifty-Eighth Annual Meeting, American Society for Testing Materials, Atlantic City, N.J., June 30, 1955. (ASTM Special Technical Publication No. 174). 8vo, pp. [iv +] 193. Illustrated. Philadelphia, Pa., 1956: The Society. (Price $3.50; to Members, $2.65).

BELAN, F. I. "*Die Rationalisierung der Arbeit in Wasseraufbereitungsanlagen metallurgischer Betriebe.*" (Übersetzung aus dem Russischen; deutsche Redaktion, A. Splittgerber). 8vo, pp. 144. Illustrated. Berlin, 1956: VEB Verlag Technik. (Price DM. 17.40).

BOLCHOWITINOW, N. F. "*Stahl, Eisen, NE-Metalle und ihre Wärmebehandlung.*" (Übersetzung aus dem Rüssischen). 8vo, pp. 435. Illustrated. Berlin, 1955: VEB Verlag Technik. (Price DM. 42.60).

BRAUN, K. "*Die Öfen der Eisenhüttenwerke.*" Band I. "*Wärme-, Gluh- und Schmelzöfen.*" 8vo, pp. 228. Illustrated. Leipzig, 1955: Fachbuchverlag. (Price DM. 18.–).

"*Brazilien.*" [Bearbeited von Walter Lauersen, Hans-Joachim Otto, Richard Salomon, Dieter Anderson. (Stahlwirtschaftliche Länderberichte, H.3). 8vo, pp. viii + 162. Illustrated. Kiel, 1955: Institut für Weltwirtschaft and der Universität Kiel gemeinsam mit der Wirtschaftsvereinigung Eisen- und Stahlindustrie. (Price DM. 18.–).

BRITISH CAST IRON RESEARCH ASSOCIATION. "*Conference on Foundry Ventilation and Dust Control, Harrogate, 27th–29th April, 1955.*" *Proceedings.* La. 4to, pp. 257. Illustrated. Alvechurch, Birmingham, 1956: The Association. (Price 60*s.*).

BRITISH STANDARDS INSTITUTION. *British Standards Yearbook* 1956. 8vo, pp. 460. London: The Institution. (Price 12*s.* 6*d.*).

BRITISH STANDARDS INSTITUTION. B.S. 2740: 1956. "*Simple Smoke Alarms and Alarm Metering Devices.*" 8vo, pp. 15. Illustrated. London, 1956: The Institution. (Price 3*s.*).

BRITISH WELDING RESEARCH ASSOCIATION. "*Brazing.*" Prepared by E. B. G. Trehearne. La. 4to, pp. 28. Illustrated. London, 1956: The Association. (Price 5*s.*).

BUREAU OF MINES. *Minerals Yearbook, Fuels. II.* 1953. Large 8vo, pp. 478 + viii. Washington, 1956: U.S. Govt. Printing Office. (Price $2.25).

CAMPBELL, I. E. (Editor-in-Chief). "*High Temperature Technology.*" (Sponsored by the Electrochemical Society). La. 8vo, pp. 526. Illustrated. New York, 1956: John Wiley & Sons, Ltd.; London: Chapman & Hall, Ltd. (Price $15.00).

"*Chili.*" (Stahlwirtschaftliche Länderberichte, H.2.). 8vo, pp. vii + 103. Illustrated. Kiel, 1955: Institut für Welt-

wirtschaft an der Universität Kiel gemeinsam mit der Wirtschaftsvereinigung Eisen- und Stahlindustrie. (Price DM. 12.–).

DEITZ, VICTOR R. "*Bibliography of Solid Adsorbents, 1943 to 1953.*" An Annotative Bibliographical Survey. (National Bureau of Standards Circular 566, March 1, 1956). La. 4to, pp. vi + 1528. Washington, D.C., 1956: Government Printing Office. (Price $8.75).

DEUTSCHE AKADEMIE DER WISSENSCHAFTEN ZU BERLIN. "*Georgius Agricola. 1494–1555.*" Zu seinem 400. Todestag. 21. Nov. 1955. 4to, pp. 376. Berlin, 1955: Akademie-Verlag. (Price DM. 38.–).

DONIKE, WILHELM. "*Schmelzen und Gattieren in der Eisengiesserei.*" 8vo, pp. 192. Berlin [1956]: Fachverlag Schiele und Schön. (Price DM. 19.50).

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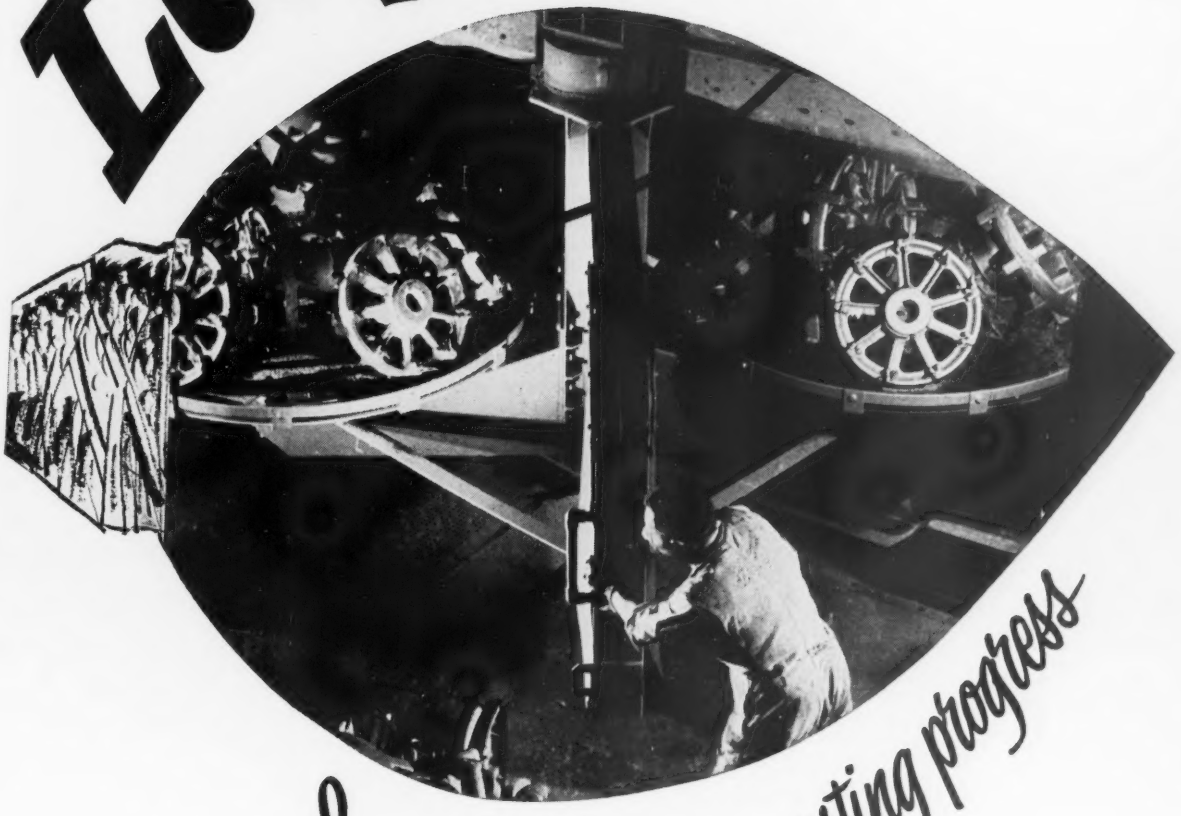

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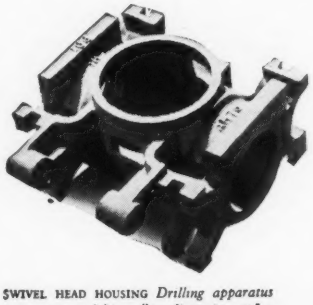

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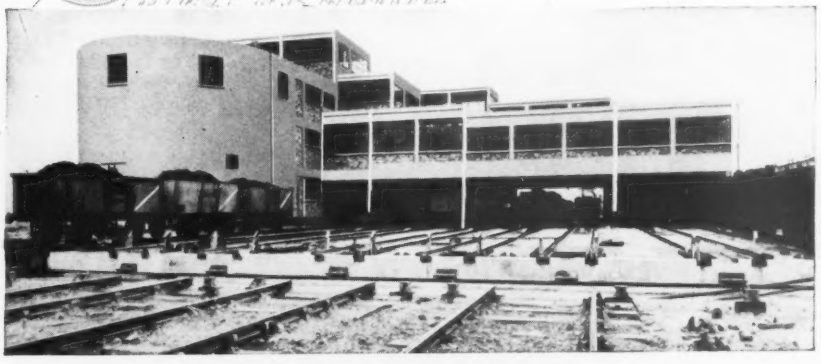

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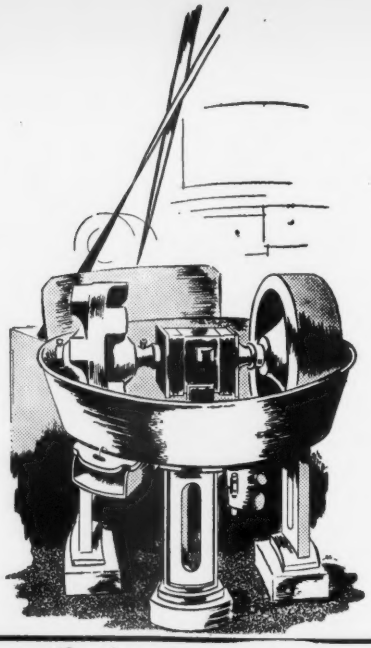

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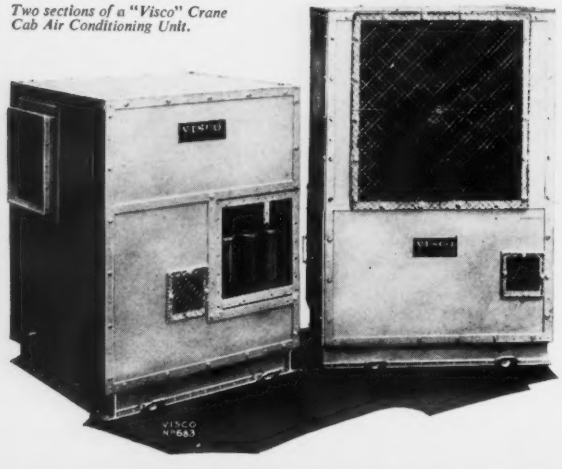

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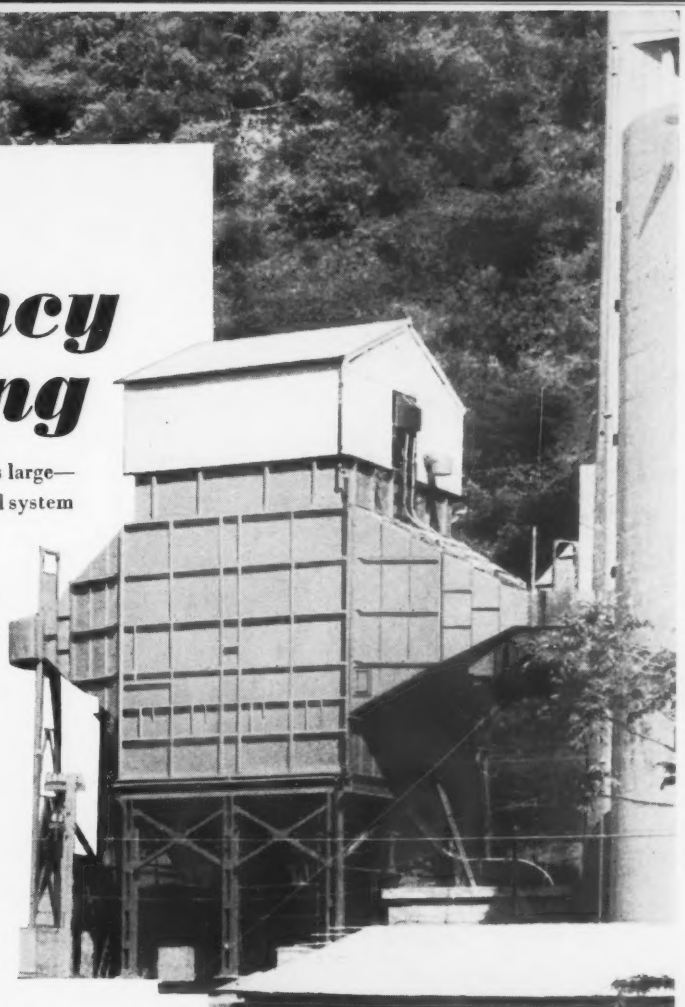

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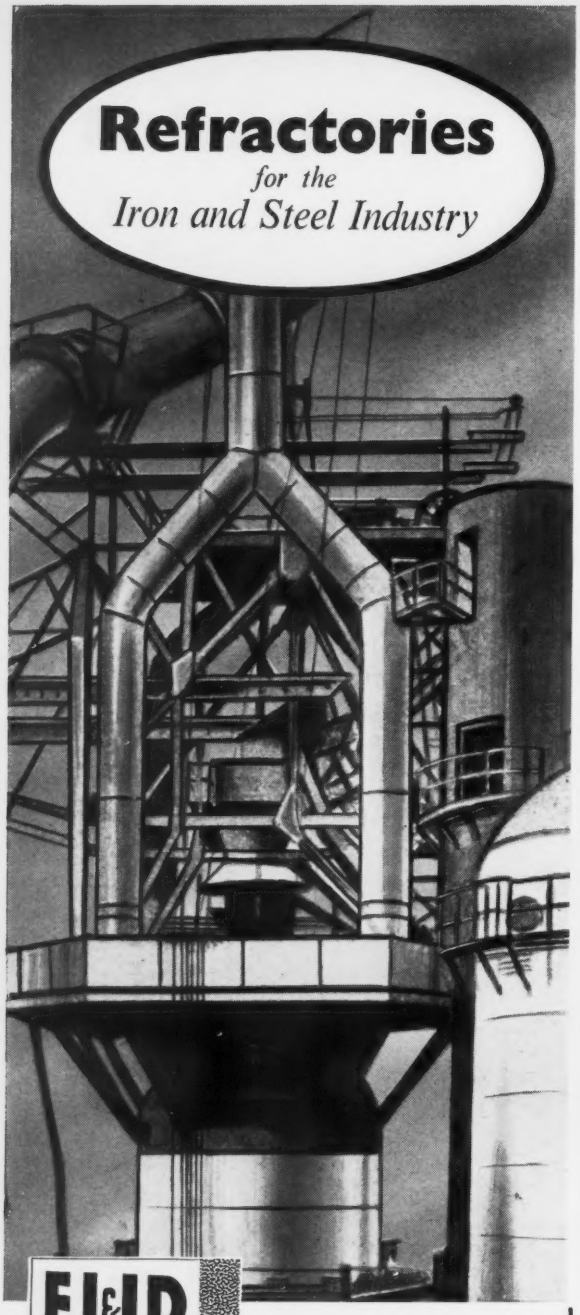

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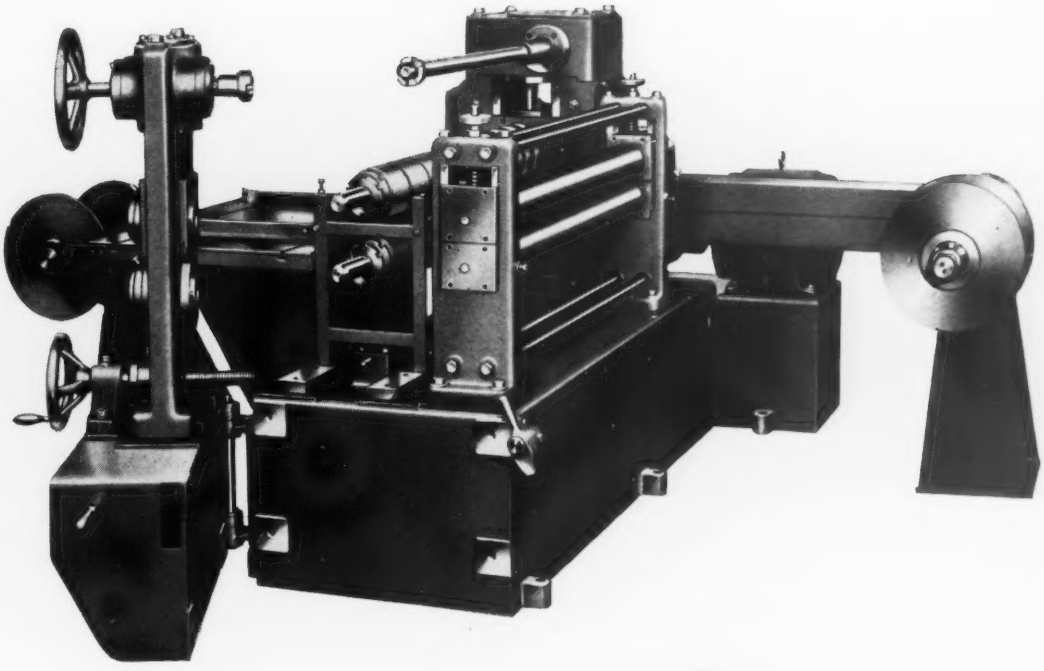

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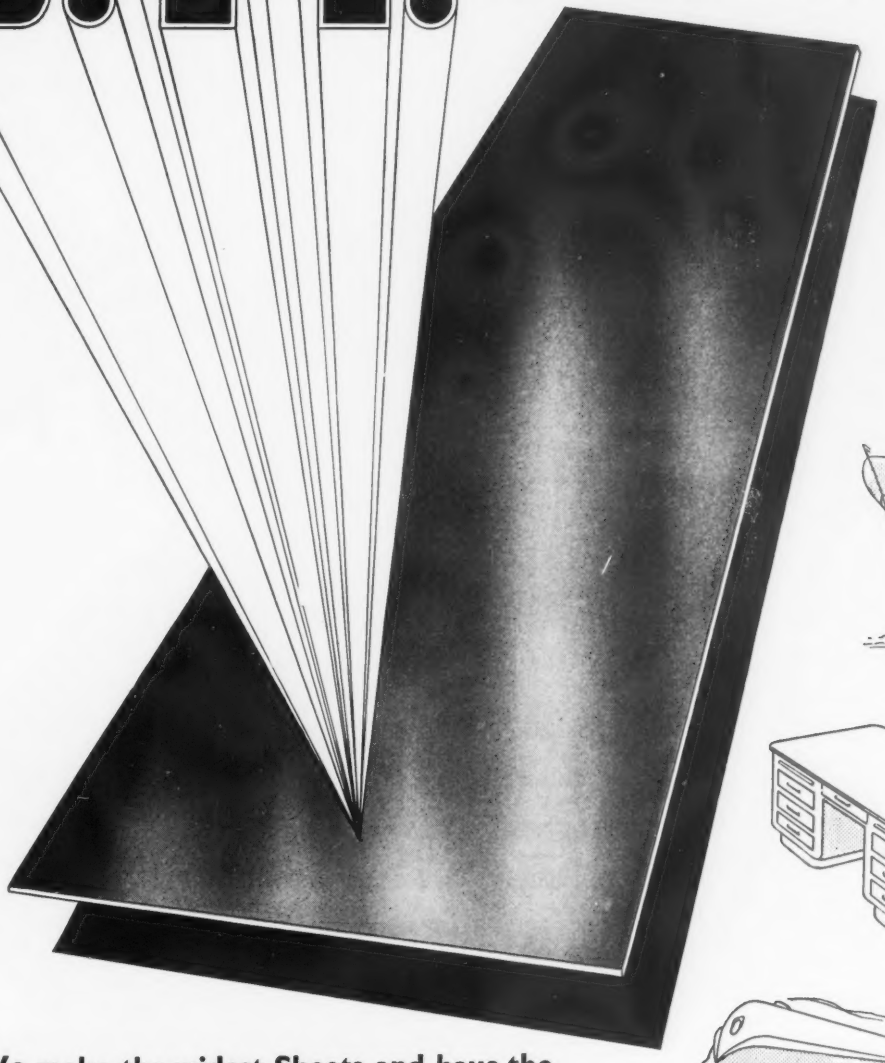

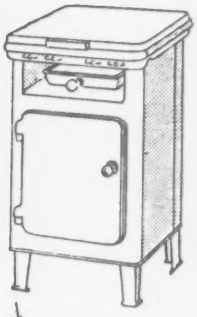

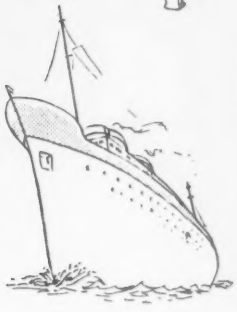

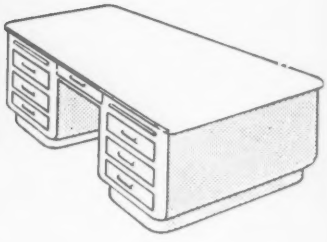

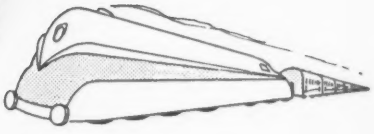

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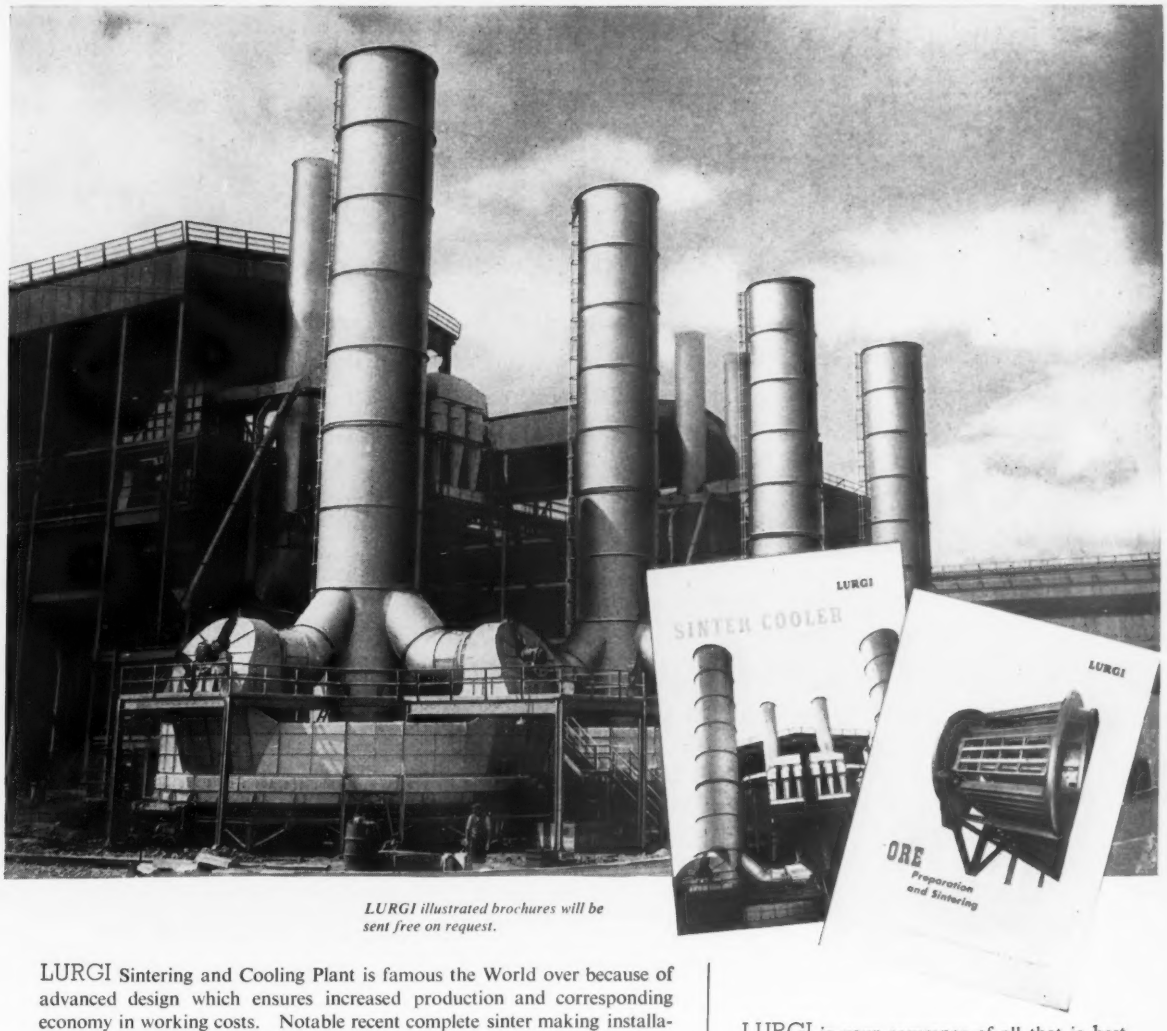

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The first five papers add considerably to present knowledge of the physics and chemistry of the sintering process. The following seven papers report industrial research on the production of sinter, and many of the findings and conclusions in these papers have already influenced plant design and practice to good effect. In the next two papers the beneficial influence of sinter on the productivity and economy of iron production in the blast-furnace is discussed.

In addition, three recently published papers, although not discussed at the Symposium, are included in this report because of their value and relevance to the papers that were presented.

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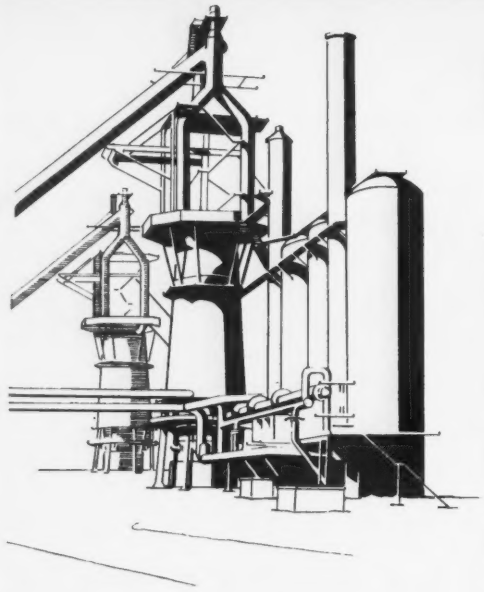

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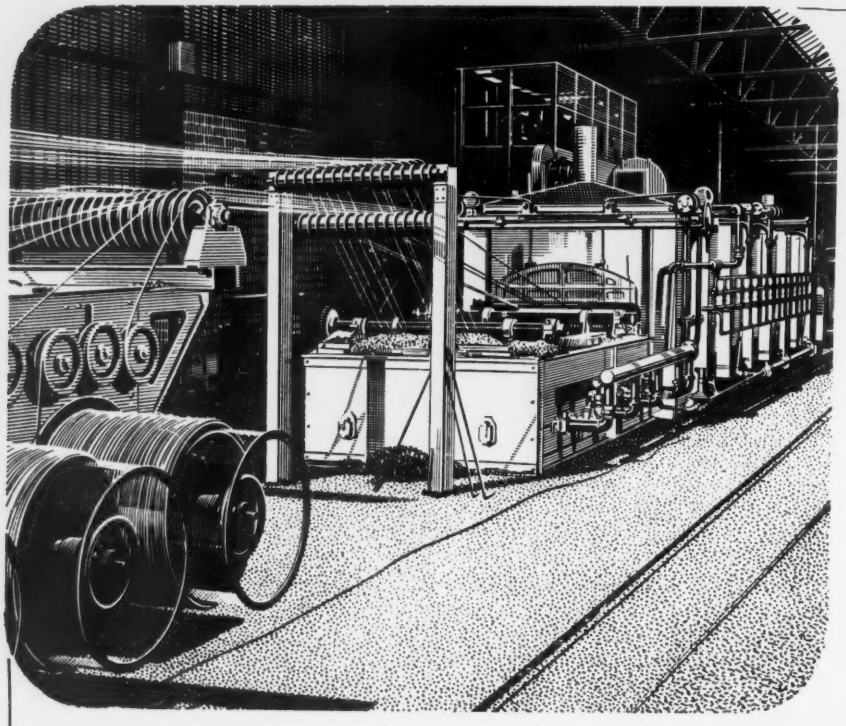

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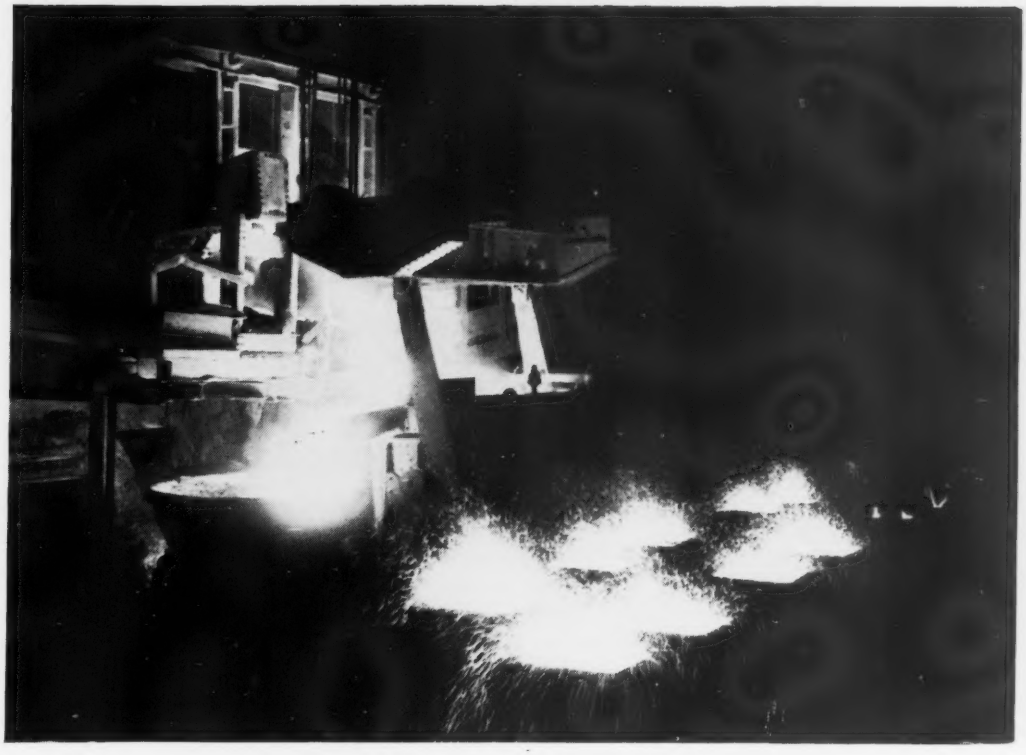

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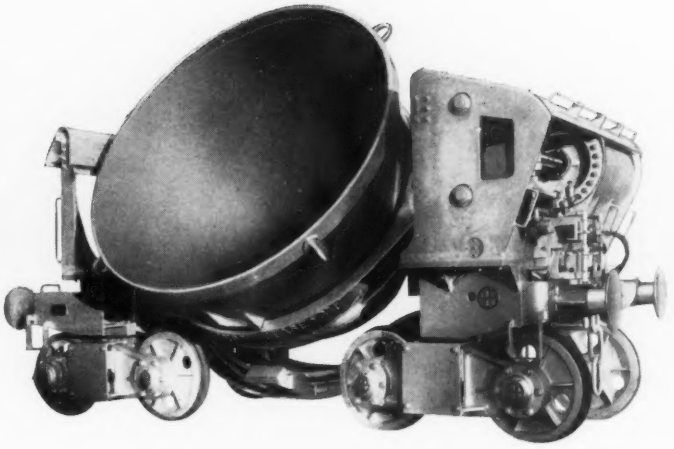

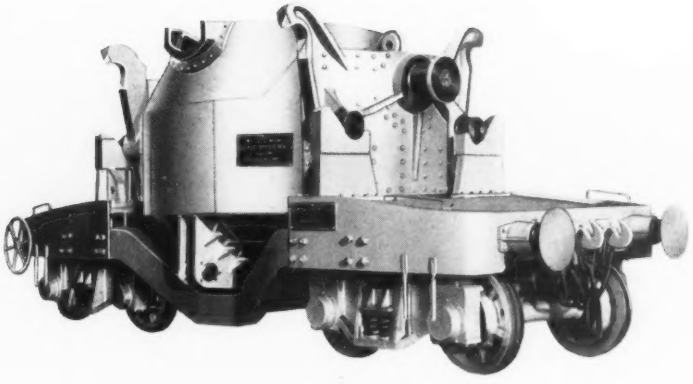

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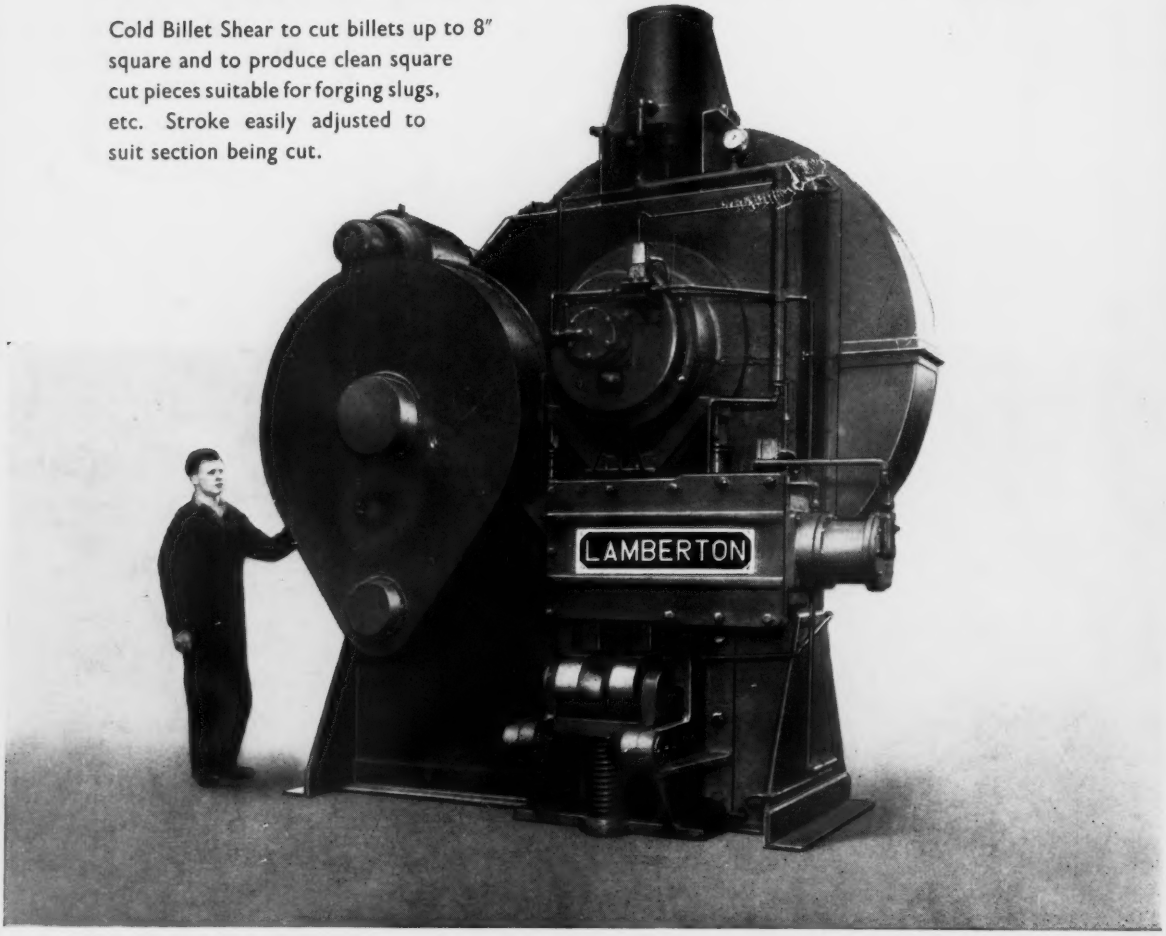

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